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A QUANTITATIVE ANALYSIS OF GROWTH IN CERTAIN HUMAN SKULL DIMENSIONS

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INTRODUCTION

IN THE *American Journal of Anatomy* for March, 1941, there appeared the Ph.D. thesis of Dr. Allan G. Brodie, entitled "On the Growth Pattern of the Human Head." It dealt with linear and angular measurements derived from the roentgenograms of twenty-one male whites, taken at regular intervals as the subjects passed from *aet.* 3 months to 8 years. Dr. Brodie did not attempt a mathematical analysis. His main conclusions, as far as relevant to the present topic, were:

"... that the anterior portion of the cranial base is longer at three months than is the posterior, but that postnatal growth of the two is almost equal ... After 1½ years the growth of the various segments comprising the cranial base may be represented by straight lines. The absolute size of even the relative proportions of the cranial base are shown to have no influence on type. The conformation of the skull is determined by the third month of life and thereafter does not change ..."

[Using the line mid-sella to nasion (S-N) as a reference, the indication is] "that the brain-case growth is slightly greater than face growth until 9 months, after which there is no change in angular relation between the anterior nasal spine, the floor of the nose and the cranial base. The anterior nasal spine follows a steady downward and forward course ...

"A study of the patterns of individuals revealed that all have the same basic conformation . . . In some the face seemed back under the brain-case, while in others the opposite was true . . .

". . . it seems that the morphogenetic pattern of the human skull is established at a very early age and that once attained it does not change. The plotting of growth increments of all of these parts reveals the gradient curves typical of neural growth. This would indicate that, after birth at least, each part and probably each bone is growing at a constantly diminishing rate. These various rates, however, are so integrated that the growth progress of the various anatomical points falls on a series of straight lines." (*Op. cit.* pp. 257-259.)

Dr. Brodie, it turned out, has been interested in D'Arcy Thompson's studies. The present writer has been studying the latter's method of distorted coordinates in application to ontogenetic development and phylogenetic evolution, with the object of eventually working out some functional formulae—so that Brodie's study has been most welcome. And since his raw data were not included in his published thesis, Dr. Brodie has very generously furnished them to me, with *carte blanche* for their manipulation. Hence my debt for the opportunity of a most interesting analysis.

Scammon and Calkins have published field graphs, but no raw data, in their "Growth of the Human Body in the Fetal Period", for a large mass of fetal material. They refer various body dimensions to the crown-heel length as a norm, thus eliminating the time factor and obtaining purely somatic ratios. By observation alone they have fitted straight lines to these scatters, and have evaluated the formula for the slope, $y = ax + b$. Huxley, however, has said (*Problems of Relative Growth*, p. 133) that he had not had the opportunity to analyze Scammon's data, but that he inclined to the belief that what he terms his heterogonic formula would fit them better. This formula is merely the exponential one, $y = a\epsilon^{bx}$, and it is the first formula I should choose for fitting Scammon's data; however, I do not have them.

It were, however, strange indeed if fetal growth followed a different pattern from post-natal. But be that as it may, the data of Brodie lend themselves to the questions: Is relative growth in man of the rectilinear type mentioned, or is it transcendental? What are the patterns of growth with respect to time? Can velocity and acceleration of growth be measured and evaluated in clear mathematical terms? Are there indications of "spurts" in growth, as sometimes believed? How measure the individual's values with respect to the mean trends of his group?

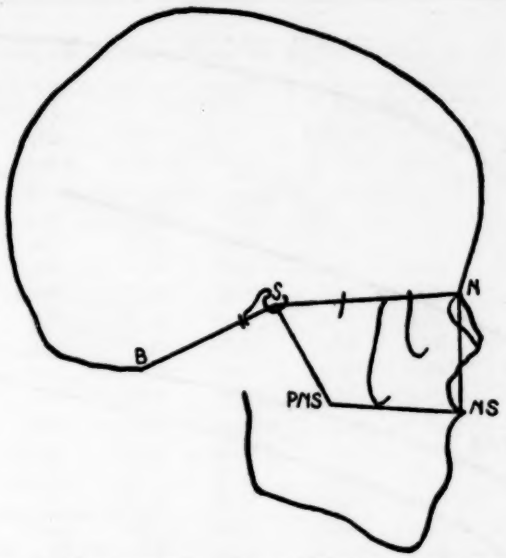

FIG. 1. MEASUREMENTS DEALT WITH IN THIS STUDY
(Compare Brodie's Fig. 2, from which this is adapted.)

The quotations from Brodie's study confine us to the matter of the muzzle; particularly to the quadrangle blocked out in our Fig. 1 by the points S-N-NS-PNS. We shall eschew the problem of angles, and merely remark in passing that the present quadrangle does change shape throughout development, somehow; and that the angle B-S-N increases with growth of the head.

PART ONE

I

We shall accept Brodie's mean values, and operate upon them.

Fig. 2 plots the means of B-S, S-N, N-NS, NS-PNS against the time t. The curves were fitted on the assumption that they are logarithmic. The fit is very close to the empirical data. We obtain for these curves the values:

	Formula	
Growth of	$y = a + bt + c \log t$	y_0
B-S	$y = -.182 + .583\,t + 3.476 \log t$	43 mm.
S-N	$y = .53 - .1333\,t + 12.47 \log t$	50 mm.
N-NS	$y = 4.528 + .383\,t + 7.216 \log t$	25 mm.
NS-PNS	$y = .5215 + .252\,t + 5.94 \log t$	34 mm.

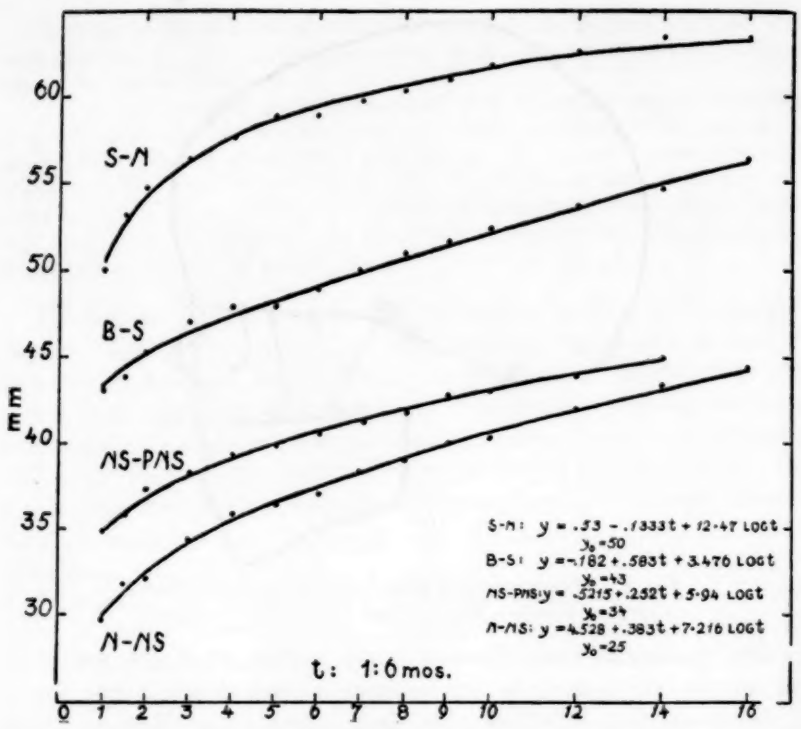

FIG. 2. GROWTH CURVES OF FOUR CRANIAL DIMENSIONS, PLOTTED AGAINST TIME *t*

(The values for the constant *a* depend upon the location of the movable axes of reference. Thus, in Table 1, the O-point for the *y*-values was arbitrarily placed as indicated under the y_0 column. In all cases, *t* was taken in units of 6 months; so that when, e.g. $t = 6$, the age was 3 years.)

It can thus be said quite definitely that, with respect to time, the growths of these dimensions in man, in so far as the data obtain, are logarithmic—not a surprising conclusion.

Observation of persons or photographs can lead one to imagine that, during the later years of the period studied, growth dimensions are maintaining certain constant ratios to each other, and that their coordinate plotting therefore would yield rectilinear slopes. Now,

TABLE 1

Empirical and calculated values of y, for* $y = a + bt + c \log t$

t	N-S		N-NS		NS-PNS		B-S	
	Empir. (*mm.*)	Calc. (*mm.*)	Empir. (*mm.*)	Calc. (*mm.*)	Empir. (*mm.*)	Calc. (*mm.*)	Empir. (*mm.*)	Calc. (*mm.*)
1	0	-4	4.75	4.91	0	.40	.73	.77
1.5	3.00	2.72	6.75	6.37	.75	1.31	1.63	1.94
2	4.5	4.02	7.12	7.46	2.00	2.03	3.29	2.81
3	6.25	6.08	9.25	9.12	3.91	3.23	4.00	4.07
4	7.5	7.51	10.75	10.40	4.81	4.24	5.12	5.11
5	8.75	8.58	11.50	11.48	4.83	5.16	5.85	5.94
6	8.75	9.43	12.00	12.44	5.77	6.02	6.60	6.65
7	9.75	10.12	13.25	13.30	6.87	6.83	7.25	7.31
8	10.25	10.72	14.00	14.10	7.90	7.62	7.75	7.90
9	11.00	11.20	15.00	14.85	8.65	8.38	8.78	8.46
10	11.75	11.66	15.25	15.57	9.21	9.12	9.00	8.98
12	12.5	12.37	17.00	16.90	10.58	10.57	9.75	9.96
14	13.5	12.90	18.50	18.15	11.60	11.97	11.00	10.86
16	13.5	13.40	19.35	19.35	13.32	13.33	....	....
	$y_0 = 50$ mm.		$y_0 = 25$ mm.		$y_0 = 34$ mm.		$y_0 = 43$ mm.	

* Empirical data are Brodie's.

mathematically it is a very simple matter to view these growths as speed-time phenomena, and measure the regression of length upon time. In other words, we may calculate the velocity and the acceleration of growth by taking the first and second derivatives of our original equations. (Table 1a.) Where $y = a + bt + c \log t$, we obtain the velocity

$$\frac{dy}{dt} = \frac{.4343\ c}{t} + b.$$

This gives us

	Velocity
B-S	$\frac{1.51}{t} + .583$
S-N	$\frac{5.41}{t} - .1333$
N-NS	$\frac{3.13}{t} + .383$
NS-PNS	$\frac{2.58}{t} + .252$

TABLE 1a

Velocities of growth in time

$\frac{dy}{dt} = \frac{.4343\ c}{t} + b$. Cross line marks value beyond which $b > \frac{.4343\ c}{t}$

t	N-S $b = -.1333$	N-NS $b = .383$	NS-PNS $b = .252$	B-S $b = .583$
1	5.28	3.96	2.83	2.09
1.5	3.48	2.47	1.97	1.59
2	2.57	1.95	1.54	1.34
3	1.67	1.43	1.11	1.09
4	1.22	1.17	.90	.96
5	.95	1.01	.77	.88
6	.77	.90	.68	.83
7	.64	.83	.62	.80
8	.54	.77	.57	.77
9	.47	.73	.54	.75
10	.41	.70	.51	.73
12	.32	.64	.47	.71
14	.25	.61	.44	.69
16	.205	.58	.41	.68
*				

* When $t = 40.6$ (20.3 years), $\frac{5.41}{t} - .1333 = 0$.

Fig. 3 plots these curves. They are exceedingly interesting. Curve S-N crosses both N-NS and NS-PNS, but these two do not cross each other. Curve B-S crosses all other three. It is small wonder that, for a time at about age 2-3, growth seems to the eye to be proceeding apace. Also, perhaps the sudden yet obviously quite rational and law-abiding leveling down of all growth curves is responsible for Brodie's consideration that by this age the patterns are "established". But after this age, as the curves again fan out a little, some changes in proportions should again become obvious even to the eye.[1]

I think it is worth more than a casual thought to observe that the line N-S is related to the growth of the pre-chordal brain, the line

[1] This supposition, Dr. Brodie assures me, does not tally with his roentgenograms.

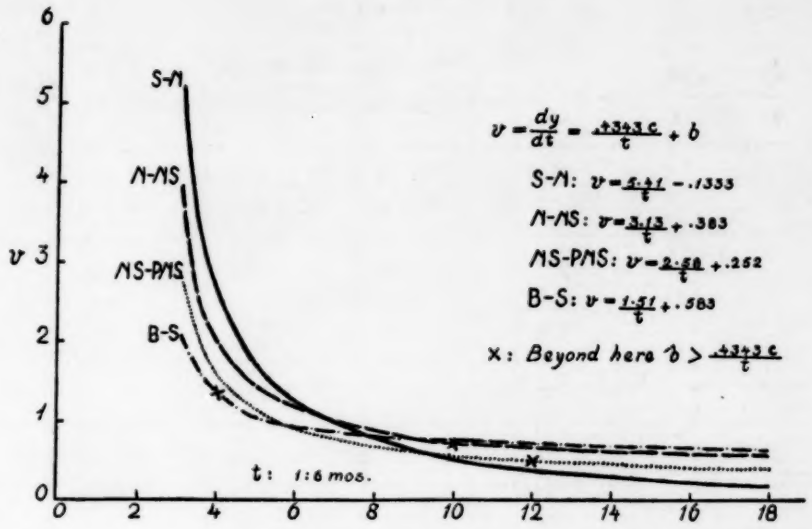

FIG. 3. VELOCITIES OF GROWTH OF FOUR DIMENSIONS, PLOTTED AGAINST TIME *t*

B-S to that of the parachordal brain, while the other two lines, which do not cross each other, are both muzzle lengths. In a plantigrade mammal, the nasal roof and the hard palate both project out in front of the brain case, and the angle between them is relatively slight. In man the growth rates evidently have fallen far below those for prognathous mammals; but the fact that both are morphologic muzzle lengths should speak for their closer correlative growth. (Indeed, the whole problem of correlative evolution of upper-face length and hard palate is still far from solved. The quantitative behavior of these two dimensions, and their relation to a prechordal brain-base, compared, e.g. in horses, dogs, lemurs, spider and howler monkeys, baboons, gorillas, and man should be a worthy study.)

Both the constants *b* and *c* control the velocity. I have marked with a cross the points on the curves where *b* becomes larger than $\frac{.4343\,c}{t}$. On one of the curves, this never happens.

From the velocity we derive the acceleration. We have, acceleration:

$$\frac{d^2y}{dt^2} = \frac{-.4343\,c}{t^2}$$

	Accelerations
B-S	$\frac{-1.51}{t^2}$
S-N	$\frac{-5.41}{t^2}$
N-NS	$\frac{-3.13}{t^2}$
NS-PNS	$\frac{-2.58}{t^2}$

Only the constant c is involved in acceleration. The curves would not cross each other. By age 3 or so, the acceleration is obviously approaching very close to 0, but without ever reaching it mathematically. The flatness of an exponential or a logarithmic curve at certain values of x and y is what may give a spurious impression of constancy.

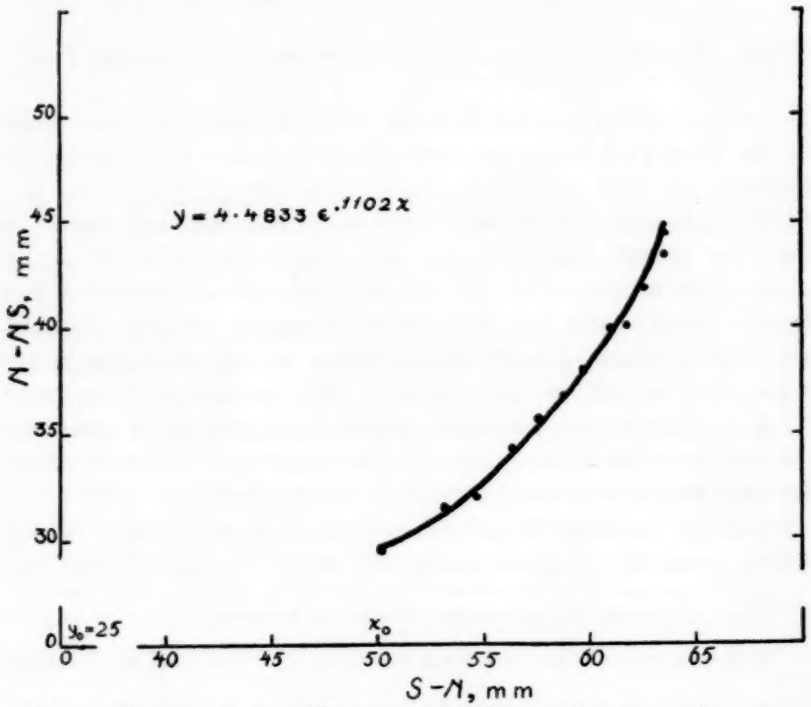

FIG. 4. REGRESSION OF THE GROWTH OF THE NASION-NASOSPINALE LENGTH UPON NASION-SELLA TURCICA LENGTH

Recapitulating, the growth pattern of S-N starts with a high value at *aet.* 6 months; it rises at first more steeply, but levels off more rapidly than other curves (Fig. 2); the velocities are momentarily almost equal at about age 2¼-3½, depending upon the curves considered; but the decelerations distinctly are not. For instance, after this time period the velocity of N-NS is greater than that of S-N; hence the face length gains notably over length of pre-chordal brain case. But there has been no disturbance in the formulations of the respective curves.

II

We may next inquire into the nature of the relationship of one growth curve to another. Will their coordinate plotting yield a straight line? Adopting or adapting Brodie's scheme of using S-N as a reference line, we submit Fig. 4, where N-NS is plotted against S-N. This obviously is not a straight line. It negates any notion of universal constancy in relative growth in man. But we shall not generalize beyond this point. Only a large number of cases, of which the present one is a sample, would justify the assertion, no matter how probable it might seem already, that all ratios behave after the same general pattern.

But, for the present curve, the formula $y = ae^{bx}$ fits admirably. In Fig. 4, I have drawn it according to the values from that formula, and again according to the ratio $\frac{y}{x} = \frac{4.528 + .383\ t + 7.216 \log t}{.53 - .1333\ t + 12.47 \log t}$. The results, it will be seen, have been identical. The pertinent data are given in Table 2. Again we can obtain velocity and the acceleration of N-NS (=y) with respect to S-N (=x). We have

Regression of y on x	$y = a\,e^{bx}$	$4.4833\ e^{.1102x}$
Velocity	$\frac{dy}{dx} = ab\,e^{bx}$	$.494\ e^{.1102x}$
Acceleration	$\frac{d^2y}{dx^2} = ab^2\,e^{bx}$	$.0545\ e^{.1102x}$

Obviously, since the equations are transcendental, the values cannot be constants. Instead, as x increases, y increases exponentially. It must be the "flatness" of such a curve at the higher values of x and y, and the contrast in its sloping at these to the more gradual sloping

TABLE 2

N-NS as y referred to S-N as x

Formula: $y = a\epsilon^{bx}$. Empirical and calculated values of y.

EMPIRICAL x (*mm.*)	EMPIRICAL y (*mm.*)	CALCULATED y (*mm.*)
0	4.75	4.48
3.0	6.75	6.24
4.5	7.12	7.36
6.25	9.25	8.92
7.5	10.75	10.24
8.75	11.50	11.73
8.75	12.00	11.73
9.75	13.25	13.11
10.25	14.00	13.86
11.00	15.00	15.06
11.75	15.25	16.34
12.5	17.00	17.73
13.5	18.50	19.80
13.5	19.35	19.80
$y_o = 50$ mm.	$y_o = 25$ mm.	$y_o = 25$ mm.

for low values of x and y, that have led to notions of "constancy" at the higher values and the belief that there is a change-over from some other pattern at an earlier age. It should be obvious, however, that such notions are ill-founded. But would that we had a hundred times the data Dr. Brodie has supplied!

III

Now as to the patterns of an individual, and his relations to the means of his group. With sufficient raw data, it were relatively simple to calculate the usual statistical constants; for example, we might then graph the curves of probable or standard error or those of standard deviation on each side of the curve of means; then trace an individual locus through the field and evaluate it. Studies in correlation coefficients would enrich our conceptions. But those things are not for the present.

It is clear that no single measurement demands that at a given size or time some other one must be related to it by a certain ratio. There is no such high correlation, apparently, between cranial dimensions

of man. On the other hand, we never expect to see a human with a normal-sized brain case and a nose the length of a horse's. And again, the errors of an individual with respect to his own mean tendency as it is graphed, are not necessarily due to faulty metric techniques. The irregularities may have biological foundations.

TABLE 3

Empirical and calculated data for No. 2005

S-N as y plotted against t, in $y = a + bt + c \log t$. N-NS as y plotted against S-N as x, in $y = a\,\epsilon^{bx}$. See Figs. 5 and 7.

(S-N) = y, $y = a + bt + c \log t$		(N-NS) = y, $y = a\,\epsilon^{bx}$	
Empir. (*mm.*)	Calc. (*mm.*)	Empir. (*mm.*)	Calc. (*mm.*)
2.0	3.02	4.00	4.33
5.0	4.81	5.75	5.99
6.5	6.05	7.25	6.87
7.5	7.91	8.50	7.86
8.25	9.24	9.00	8.52
9.5	10.28	9.75	9.76
10.5	11.14	10.75	10.86
11.0	11.88	11.75	11.46
12.00	12.53	13.00	12.77
13.0	13.12	13.75	14.24
13.5	13.66	15.5	15.05
14.25	14.59	15.5	16.32
15.0	15.42	17.25	17.70

Having so gone on record, we may be free to study curves of the mean tendencies of an individual. We select at random individual No. 2005. The growth of his line S-N over the period from 6 months to eight years has the value

$$y = 2.94 + .077\,t + 9.94 \log t.$$

Table 3 adduces the empirical and calculated values, the axes remaining as before: $y_0 = 50$ mm. (See also Fig. 6.) Then at the age 6 months, when the measurements began, this individual was somewhat longer in this measurement than the mean of the group. The difference for the entire age-period studied is computed simply:

$$\begin{array}{rl} \text{individual } y: & 2.94 + .077\,t + 9.94 \log t \\ -\text{group mean } Y: & -(.53 - .1333\,t + 12.47 \log t) \\ \hline \text{difference}: & 2.41 + .200\,t - 2.53 \log t \end{array}$$

in favor of the individual. His growth velocity was somewhat less than that of the mean, however, during the period in question:

$$\begin{array}{rl} \frac{dy}{dt}(\text{group mean}) & \frac{5.41}{t} - .1333 \\ -\frac{dy}{dt}(\text{individual mean}) & -\left(\frac{4.32}{t} + .077\right) \\ \hline \text{difference}: & \frac{1.09}{t} - .200 \end{array}$$

in favor of the group—until $\frac{1.09}{t} < b$; thereafter the difference begins to favor the individual (see also Fig. 7). This occurs after t becomes 5.45; that is, *aet. ca.* 2.7 years.

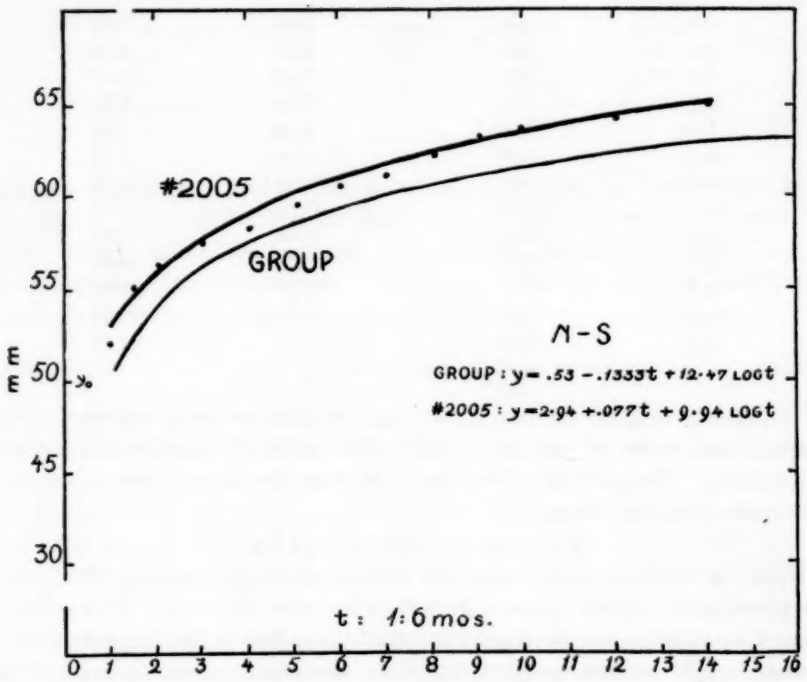

FIG. 5. MEAN GROWTH TENDENCY OF THE NASION-SELLA LENGTH IN INDIVIDUAL NO. 2005, COMPARED WITH THAT OF HIS GROUP

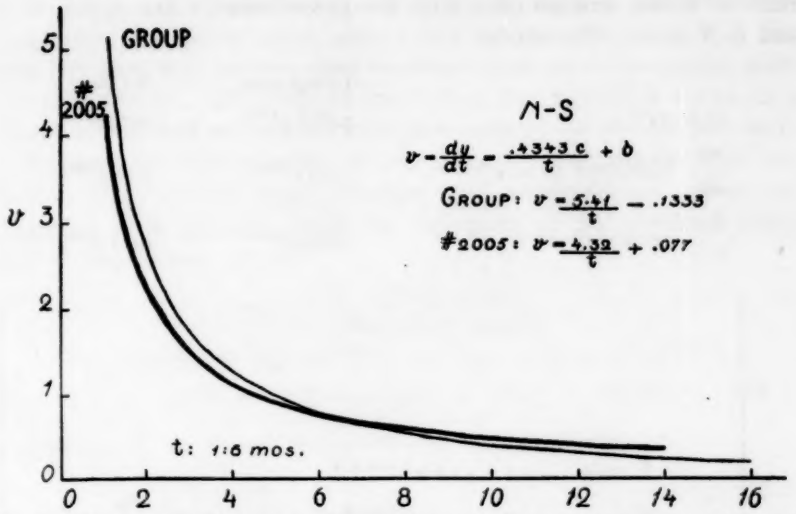

FIG. 6. VELOCITY OF GROWTH OF NASION-SELLA LENGTH IN INDIVIDUAL NO. 2005, COMPARED WITH THAT OF HIS GROUP

This behavior of the curves and the equations gives the spurious impression, if impression there is, that the individual has "picked up" over the group mean. Actually, however, there is no growth spurt at all; the loci have intersected—that is all. There is a similar behavior of loci in Fig. 3.

But No. 2005 has a smaller deceleration than the group has. This is inherent in the values of the velocity equations. For the acceleration, we have

$$\begin{array}{lll} \frac{d^2y}{dt^2} & \text{(group mean)} & \frac{-5.41}{t^2} \\ - \quad \frac{d^2y}{dt^2} & \text{(individual)} & \frac{-4.32}{t^2} \\ \hline \text{difference:} & & \frac{-1.09}{t^2} \quad : \end{array}$$

meaning that the acceleration is proceeding negatively more rapidly in the group than in the individual.

Let us now relate the measurement N-NS of the individual No. 2005 (we shall not linger to treat it to a parametric equation, as we have just done with S-N) to the measurement S-N by way of their

ratio or index, and compare with the group mean. Set N-NS $= y$, and S-N $= x$. We obtain

	Group mean	*No. 2005*
$y = a\,\epsilon^{bx}$	$4.4833\,\epsilon^{.1102x}$	$3.4914\,\epsilon^{.1084x}$
$\frac{dy}{dx}$ (velocity) $= ab\,\epsilon^{bx}$	$.494\,\epsilon^{.1102x}$	$.3785\epsilon^{.1084x}$
$\frac{d^2y}{dx^2}$ (acceleration) $= ab^2\epsilon^{bx}$	$.0545\,\epsilon^{.1102x}$	$.0411\,\epsilon^{.1084x}$

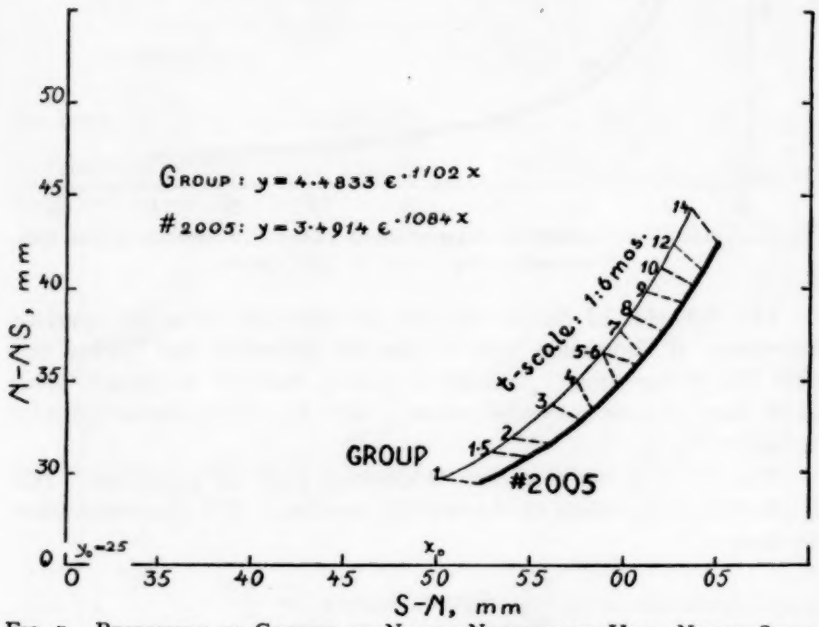

FIG. 7. REGRESSION OF GROWTH OF NASION-NASOSPINALE UPON NASION-SELLA LENGTH IN INDIVIDUAL NO. 2005, COMPARED TO THAT OF HIS GROUP

The curves for $y = a\,\epsilon^{bx}$ are plotted comparatively in Fig. 7. It will be seen that, in the growth of No. 2005, whenever the mean growth tendency of his S-N length equaled that of the group mean, his N-NS length was less; or vice versa. But this graph is independent of time. Since, however, the parameter time was furnished in the original data, we may superimpose the time-scales for both curves. The numbers running along the curve represent time in units of 6 months; the contemporaries are joined by the short ladder-rungs.

These rungs rotate to a steeper slope as development of the comparates progresses: the group mean always has a longer face per N-S line than No. 2005 has; yet No. 2005 tended to catch up on the group, without attaining it. We keep in mind that the individual curve is a smoothed one; and we shall not attempt to account for deviations from it.

It now becomes possible to calculate a ratio between the two curves; also between their velocities and accelerations. Since the logarithm of a quotient equals the logarithm of the dividend minus that of the divisor, we take

$$\log_{10} \frac{Y \text{ (group mean)}}{y \text{ (individual mean)}} =$$

$$(\log_{10} 4.4833 + \log 10^{.0478x}) - (\log_{10} 3.4914 + 10^{.047x});$$

i.e. $(.6517 + .0478x - .543 - .047x) = .1047 + .0008x.$

Therefore, $\frac{Y}{y} = 1.2726 \times 10^{.0008x}$, or $1.2726\,\epsilon^{.00184x}$;

or, inverted, $\frac{y}{Y} = \frac{.785}{\epsilon^{.00184x}}$ or $\frac{.785}{10^{.0008x}}$.

In like manner, the ratio of the velocities $Y:y$ is $1.3046\,\epsilon^{.00184x}$; that of the accelerations is $1.0313\,\epsilon^{.00184x}$.

These ratios, we note again, say nothing about the time at which the differences are occurring; they merely compare, in an individual and his group, the behavior of one variable y (the N-NS length) with that of another, x (the S-N length).[2]

As a theoretical matter, these calculations indicate what might be done with, say, Neanderthal man and *Homo sapiens,* if only we had the raw data. As for *Homo sapiens* himself, all we lack is the proper quantity of raw data that really exist for the gathering, to make possible intersexual and interracial comparisons.

The last adjective compels a further word. Anthropologists often have compared groups of humans for the sake of ascertaining their possible ancestral relationships, on the basis of adult male specimens alone; the reason being, aside from the nature of the material at hand, that the adult male climaxes the differentiation of the groups,

[2] There should be no confusion on the score of the x's and y's. Naturally, no matter what comparates we may be dealing with at the moment, that assigned to the ordinate has been called y; that to the abscissa has been called x, unless a dimension was being referred to time, when it has been called t — the convention of parametric equations of the calculus.

and is therefore somatoscopically or cranioscopically more easily distinctive than the female. The writer wishes to go on record as preferring that we should think of *both* sexes, in their adult condition at least, as quasi-end-products of quantitatively determinable growth-rates. An index is not enough. It has been reached by a certain road. That road may be different—the quantitative values of the equations that express it—from the one followed by another type of human who has achieved a closely similar indicial value. In such a conception, both sexes are equally important for diagnostics and equally usable. Immature material, instead of being shunned, is perhaps even more important than adult, since it is necessary for defining the curves of growth. Perhaps some of us anthropologists should invert our sense of values . . . ?

PART TWO

I

The inquiry shall now be pressed towards ascertaining the nature of the frequency distribution of the given population throughout the length of the growth period covered by the data. We need the standard deviation from the mean over the entire time-range. The case study shall be on the growth of the S-N dimension. We can safely assume that the distributions will be symmetrical about the mean. The true locus of the mean growth-tendency, $y_{(M)} = .53 - .1333\,t + 12.47 \log t$, should be flanked on either side by the loci of $y_{(M+\sigma)}$ and $y_{(M-\sigma)}$ which must likewise be logarithmic curves.

It may be well to interject a note on the shape of the field we now study. Any statistician could point out that a graph of these lines implies that our field is no longer a plane, as heretofore, but a solid. The z-axis is normal to our plane, or sheet of paper with its x- and y-axes, the frequencies pile up in the z-dimension, and every line we draw is the edge of a plane standing vertically on our sheet of paper. The path now taken by our data, that is, the loci of the points representing the individual growth patterns, summate in a long, mound-like figure resting on our paper (something the shape of that produced on a lawn by the tunneling of a mole); any cross section of this mound is the area defined by the frequency curve at the given moment of time.

The first step is to obtain $\pm\sigma$ for the value of the mean (M) at every time interval t. This is easily done through standard procedure, and we obtain the results shown in Table 4.

TABLE 4

Values of m (calculated), σ and CV for growth of S-N dimension

NO. OF SAMPLES N	TIME (in 6 mos. units) t	MEAN (recalculated) M	STANDARD DEVIATION σ	COEFFICIENT OF VARIATION CV
19	1	49.96	1.86	3.72
15	1.5	53.03	1.97	3.71
11	2	54.54	2.40	4.40
20	3	56.31	2.11	3.75
20	4	57.62	2.56	4.44
18	5	58.67	2.53	4.31
19	6	58.88	2.94	4.99
21	7	59.67	2.55	4.27
20	8	60.31	2.77	4.59
21	9	61.25	2.86	4.67
19	10	61.85	2.81	4.54
21	12	62.64	3.05	4.88
21	14	63.57	3.14	4.95

Of course, with such small values of N, the standard errors will be high. But our discussion is perforce exploratory; it cannot be otherwise. Nevertheless, the methodology should demonstrate that the machinery is available whenever there is grist.

These values of σ yield the equations (with y_0 taken always at 50 mm.):

$$y_{(M+\sigma)} = 2.57 + .0166\,t + 11.95 \log t$$

$$y_{(M-\sigma)} = -1.213 - .0701\,t + 10.74 \log t.$$

The means given by Brodie's original tables were slightly rounded; but my recalculations in the table above do not materially effect the equation of the means; so the formula already given as $y_{(M)} = .53 - .1333\,t + 12.47 \log t$ can be used to obtain the values of $+\sigma$ and $-\sigma$. By proper subtractions we get

$$y_{(+\sigma)} = 2.04 + .15\,t - .52 \log t$$

$$y_{(-\sigma)} = 1.76 - .0632\,t + 1.73 \log t.$$

These values are not satisfactory. We shall attempt a closer approximation farther along. The discrepancy between $+\sigma$ and

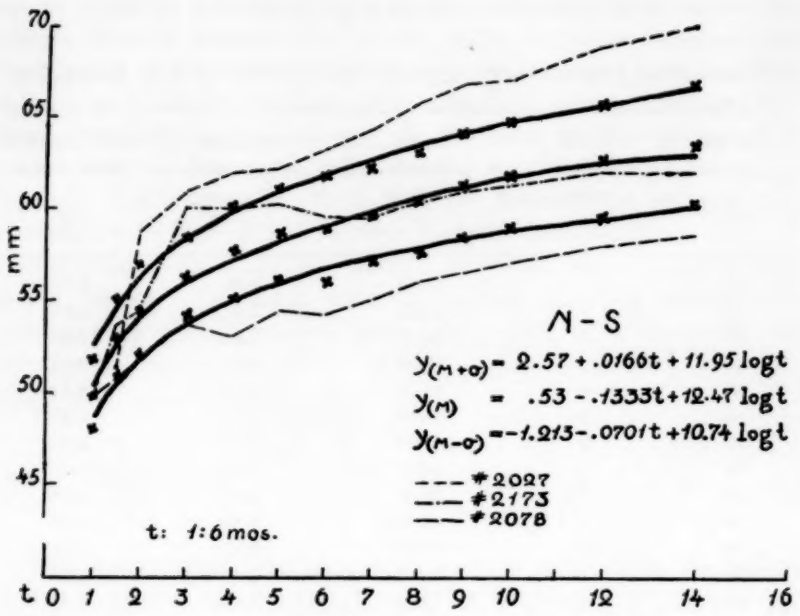

FIG. 8. FIRST APPROXIMATION OF CURVES FOR $M + \sigma$ AND $M - \sigma$ OF GROWTH OF S-N DIMENSION

Growth behavior of three individuals referred to the mean tendency and the standard deviation.

$- \sigma$ comes from our having had to use means of high error and small value of N.

Fig. 8 nevertheless plots the curves, and adds the behavior of certain individuals; but it seems supererogatory to calculate their smoothed-curve tendencies and relate them to σ and M. The technique for doing it is now obvious.

Some of the aberrant character of these lines may of course be due to inaccuracies in obtaining the raw data (they were obviously delicate to secure); on the other hand, it is fair to assume that the growths did follow some such odd courses. Thus, No. 2173 starts, at age 6 months, exactly on the line of means (50 mm., where $y = 0$); for a year and a half he keeps pretty well on that line; then he shoots suddenly up and beyond $(M + \sigma)$; he thereupon seems to rest; even a diminution is registered; thereafter he again hovers close to the mean. His total tendency is almost tantamount to the mean. No.

2027 starts below the mean yet well above $M - \sigma$, rises rapidly, and stays far above $M + \sigma$. No. 2078 also starts between M and $M - \sigma$, then drops below $M - \sigma$ and stays there.

Whatever may be the explanation, it appears that each individual has a rather well-defined mean tendency of his own—which is compensated at a later period, if at an earlier period there has been a deviation.

II

It is to be expected that the standard deviation shall increase as the mean rises. But what about the variation coefficient? Is it a constant or a variable? That is, do these individuals, as they grow older, show a group tendency to become a more varied group, or is the group tendency to vary as well defined quantitatively at an earlier age as at a later? This point has considerable biological interest.

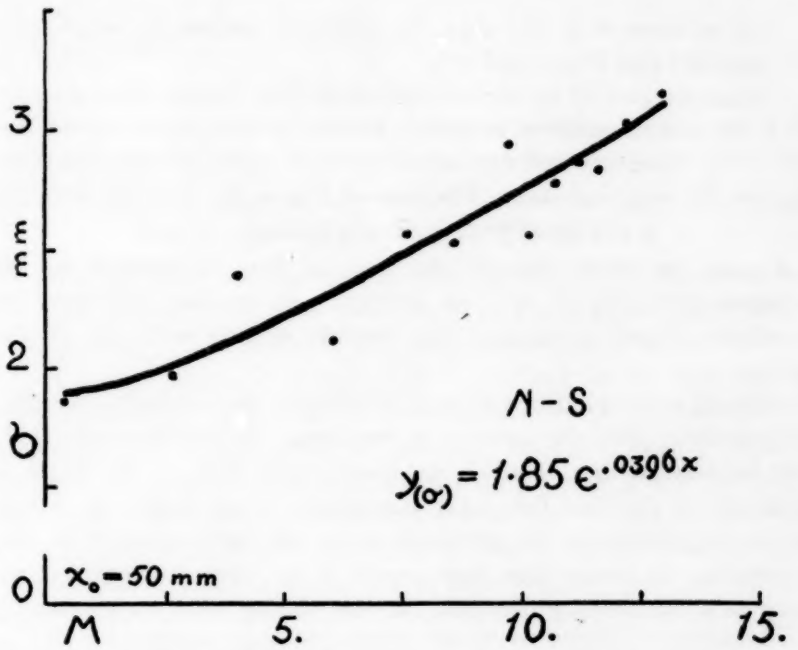

FIG. 9. THE S-N DIMENSION. INCREASE OF THE STANDARD DEVIATION AGAINST INCREASE OF THE MEAN GROWTH TENDENCY

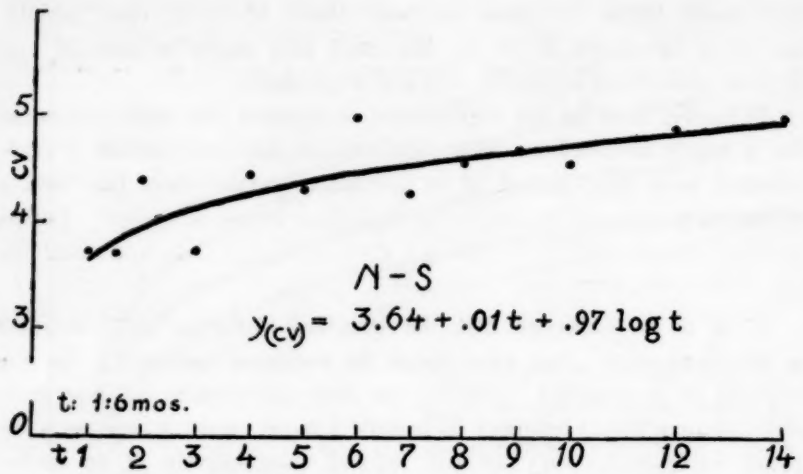

FIG. 10. THE S-N DIMENSION. INCREASE OF THE VARIATION COEFFICIENT IN TIME

Let us check it in two ways: by plotting σ against M; by plotting CV against t (see Figs. 9 and 10).

Again the paucity of our universe renders the routine determination of a line and its equation pedantic. Instead, I have merely drawn the curves by inspection, and then calculated their values and checked them against the empirical data. The line of Fig. 9 fits well the formula

$$y = 1.85\, e^{.0396x} \text{ or } y = 1.85 \text{ antilog}_{10} .0172x.^{3}$$

Likewise, the curve through the field in Fig. 10 answers to the equation $y = 3.64 + .01\ t + .97 \log t$. In any case, the variation coefficient is not a constant, but increases slightly with age of the group.

Should more raw data confirm this indication that σ actually increases exponentially with the increase in the mean, or logarithmically with the increase in time, I think we should have here as significant a principle as any that this paper has sought to set forth. It should be as suggestive to the geneticist as to the anthropologist or the anatomist. It means that there would be an increasing tendency to vary as a population grows older, at least during these early years of

[3] Average empirical $\sigma = 2.582$; average calculated from this formula $= 2.591$. We shall omit recording further check for the sake of brevity.

growth: the standard deviation is an increasing percentage of the mean, not a constant. This should also have evolutionary implications.

Again the first and second derivatives, the velocities and the accelerations, are easily figured, if desired.

III

We revert to the matter of the equations for $+$ and $-\sigma$. Let us derive these quantities this time strictly by use of curves and equations that have been smoothed.

We now have an equation for the variability of the CV. Since $\sigma = \frac{M \times CV}{100}$, we can calculate a theoretical set of σ's for the values of M yielded by the equation $y_{(M)} = .53 - .1333\ t + 12.47 \log t$. These σ values will deliver equations for $(M + \sigma)$ and $(M - \sigma)$ that are symmetrical about the curve of the mean.

The formula $y_{(CV)} = 3.64 + .01\ t + .97 \log t$ is sufficiently accurate for use.[4]

We now have

$$y_{(M+\sigma)} = 2.3655 - .1255\ t + 13.45 \log t$$
$$y_{(M-\sigma)} = -1.297 - .1441\ t + 11.497 \log t;$$

also, by extracting $(y_{(M)} = .53 - .1333\ t + 12.47 \log t)$, we get

$$y_{(+\sigma)} = 1.8355 + .008\ t + .98 \log t$$
$$y_{(-\sigma)} = 1.827 + .01\ t + .973 \log t;$$

which (slide-rule) calculations are quite satisfactory. (Note that the value of σ differs from that of CV only by a quantity in a : $3.64 - 1.83 = 1.81$.) The velocities and accelerations are given in Table 5.

In passing from $(M + \sigma)$ to $(M - \sigma)$, both the b— and the c— factors decrease. This should be borne in mind when analyzing growth curves of individuals: Does, for instance, the curve parallel more or less the (M)-curve ? Does the curve start above or below the (M)-curve and then cross it somewhere?

In conclusion, may I simply add that only an extension of our data back to earlier periods and forward to later ones, will show us whether

[4] Again to conserve space, let it suffice that the average of the empirical CV's of Table 4 is 4.408; that of our theoretical CV's from our formula is 4.375. This is tolerable under the circumstances.

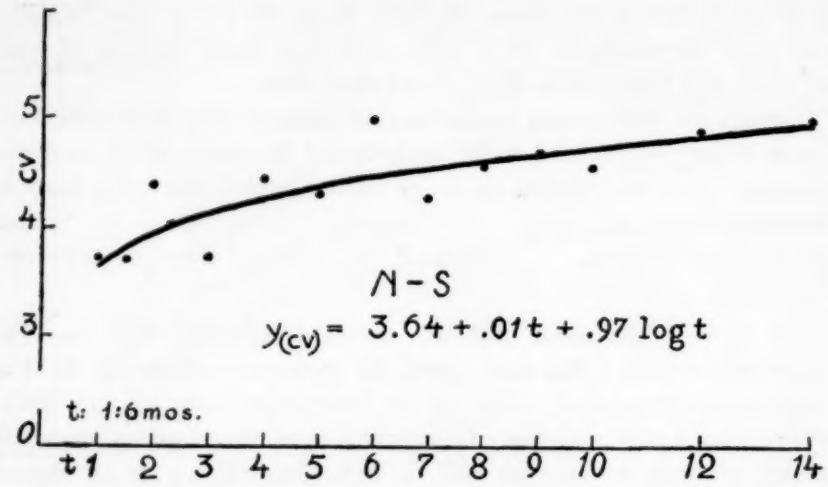

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TABLE 5

Velocities and accelerations of the curves for $(M + \sigma)$, $(M - \sigma)$, (M), $+\sigma$, *and* $-\sigma$

	VELOCITY $\frac{dy}{dt} = \frac{.4343\ c}{t} + b$	ACCELERATION $\frac{d^2y}{dt^2} = \frac{-.4343\ c}{t^2}$
$(M + \sigma)$	$\frac{5.84}{t} - .1255$	$\frac{-5.84}{t^2}$
(M)	$\frac{5.41}{t} - .1333$	$\frac{-5.41}{t^2}$
$(M - \sigma)$	$\frac{4.99}{t} - .1441$	$\frac{-4.99}{t^2}$
$+\sigma$	$\frac{.426}{t} - .008$	$\frac{-.426}{t^2}$
$-\sigma$	$\frac{.423}{t} - .01$	$\frac{-.423}{t^2}$

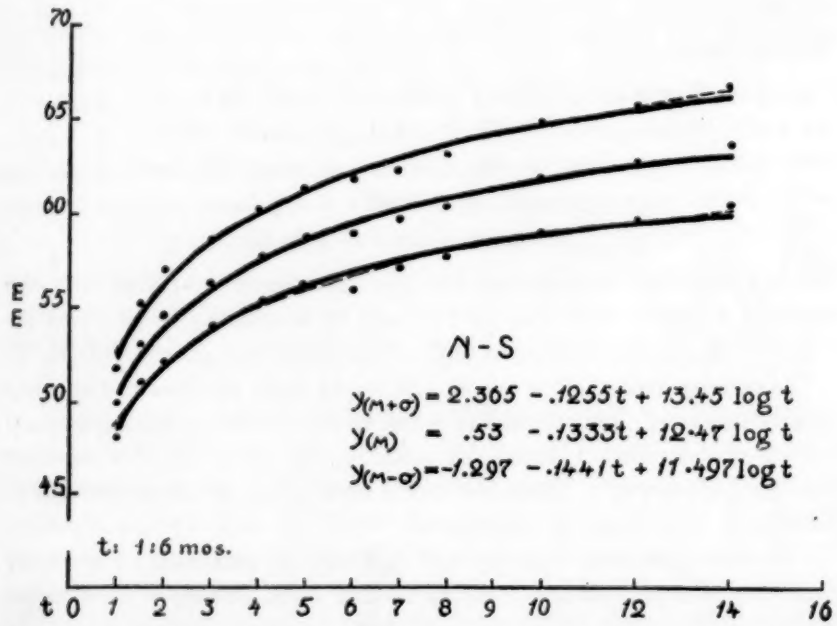

FIG. 11. THE S-N DIMENSION. CURVES OF $M + \sigma$, $M - \sigma$, AND M DERIVED BY WAY OF THE VARIATION COEFFICIENT

Broken lines: Lines of the first approximation superimposed.

or not we have merely been working with fragments of curves that actually are logistic. Such a discovery, however, would only extend, and not invalidate the present findings.

SUMMARY

It has been demonstrated that growth of the dimensions considered is logarithmic in time.

When a certain measurement has been ratioed to another, the relative growth is exponential. But we are not ready to make this a generalization. We are satisfied, however, that only in exceptional cases—which nevertheless would still be consistent with the generalization—should we expect any simple rectilinear ratio (of the type $y = ax + b$). The ratio between two dimensions is far more likely to alter curvilinearly.

The logarithmic and exponential patterns herein adduced have been measured quantitatively; and their velocities and accelerations have been calculated. These quantities cannot become constants, but are variable and dependent functions.

As a case-study, an individual has been subjected to the same process of analysis; and thereupon he has been compared quantitatively with the behavior of the means of his group.

The curves and equations for the standard deviation have been formulated for the growth pattern of one measurement with respect to time; and the velocities and accelerations for the curves of $(M + \sigma)$, $(M - \sigma)$, $+\sigma$ and $-\sigma$ have been derived.

The indication is that the variation coefficient is not constant over the age-period analyzed; instead, it increases logarithmically with time; or, the standard deviation increases exponentially against the mean.

Nothing but lack of pertinent raw data prevents application of such analysis to sex and race, as well as species, comparisons.

AN EXTRAORDINARY CASE OF OBESITY AND A REVIEW OF SOME LESSER CASES

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INTRODUCTION

A Fundamental truism of Nature is that every living organism, whether animal or plant, must, because of a uniqueness of inheritance and environment, be more or less different from all others of its kind. Naturally, this tendency to individual variation gives rise to extremes, and extremes of anything are always interesting. Especially is this true of variations in the human form. Hence the perennial interest by everyone in giants, dwarfs, circus fat people, and other fellow-citizens who happen to be the exceptions of a capricious Mother Nature.

The particular extreme to be discussed in this paper is obesity — by which is here meant bodily fatness of such pronounced degree that it puts one in the "circus fat people" class. In citing a number of individuals possessed of such extreme corpulency, the writer will first review some of the outstanding cases of the past, and will then describe in detail a young woman of today who is probably "the fattest of them all".

NOTEWORTHY INSTANCES OF FATNESS

Although countless cases of extreme obesity have occurred, and continue to occur, a survey of the medical and historical literature of the subject reveals fewer than twenty instances—even when unauthenticated ones are included—in which the person weighed 700 pounds or more. These previous instances, in ascending order of weight, are as follows:

C. F. Titman, of Philadelphia, weighed 700 pounds at the age of 36, about 1925. Granville W. Hall, of Pocomoke City, Maryland, weighed 700 pounds at the time of his death at the age of 37, in 1938.

Gould and Pyle, in their work, *Anomalies and Curiosities of Medicine* (1), mention a woman who died at the age of 25, weighing 700 pounds. Joseph Raggio, of Philadelphia, weighed 701 pounds at the age of 27, in 1933. William Campbell, of Newcastle-on-Tyne, England, weighed 728 pounds at the age of 22, in 1878. Ali Zadina, of Constantinople, Turkey, weighed 732 pounds at the age of 29, in 1929. That most famous of all fat men, Daniel Lambert, of Leicester, England, weighed 739 pounds at the age of 39, in 1809. T. A. Valenzuela, a Mexican, known in show circles as "Prince Val" and "Tom Ton", weighed 745 pounds at the age of 29, in 1924; at the time of his death, some years later, he weighed about 850 pounds. Mrs. Gertrude Karns, of Shreveport, Louisiana, weighed 745 pounds at the age of 28, in 1936. Rose Nanez, 23 years of age, in 1938, was reputed to have weighed 756 pounds. Gould and Pyle report a case from the French of a person who weighed 800 pounds. David Maquire, of Kenosha, Wisconsin, weighed 810 pounds (about 1935). Again quoting Gould and Pyle, mention is made of a colored woman who died near Baltimore, in 1888, weighing 850 pounds. Finally, there is the case of Miles Darden, probably the largest person who ever lived, who was born in North Carolina in 1798, and who died in Henderson County, Tennessee, in 1857, weighing a little over 1000 pounds!

Now, for the introduction of our present subject, Mrs. Ruth G. Pontico,[1] of Tampa, Florida (see Plate). Mrs. Pontico, who has been most kind and coöperative in supplying the details of her physical history, and who has graciously consented to this publication of the same, on April 10, 1939, at the age of 35 years, weighed 772½ pounds. Thus she has been surpassed in weight probably by not more than five persons, only one of whom was a woman. But in the scientific appraisement of obesity—that is, the *relative degree* of fatness—*height* as well as weight must be taken into account, so that the idea conveyed is that of relative girth rather than total volume.

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[1] It is with regret that we must announce that after this article had been written and set-up, word came that Mrs. Pontico had died, on November 29 last, at a hospital in Tampa, after having failed to recover from an operation for the removal of a fatty tumor from her left thigh. The formal cause of death was listed as cardiac failure. Her publicized weight just before her death was "815" pounds, and it is probable that her actual, net weight was as much as 800 pounds.—D.P.W.

THE INDEXING OF BODY BUILD

Perhaps the best way of expressing the relative fatness or leanness of a person is to relate the general width or girth of the body to the height. Where the girth measurements are unknown, an approximation of their average or general value may be arrived at by taking the square root of the weight per inch of height. This may then be converted into *relative* girth by dividing by the height. The resultant amount, when multiplied by 44 for men or 46 for women, gives an index figure of 1.00 for a person who is of perfect medium size (girth) for his or her height. In applying the index to obviously overweight persons, it may fittingly be termed "Index of Relative Obesity".[2]

In Mrs. Pontico, who is only 5 feet 5½ inches (or 65½ inches) in height, this relative obesity index is 2.41, which means that her girth, breadth, and anteroposterior depth measurments, in general, are 2.41 times as great as those of a medium-sized, properly-proportioned young woman of the same height. This is shown in detail by the separate ratios in the right-hand column of Table 1. Now, let us see how some of our other listed subjects, of known height, fare under this indexing.

---

[2] When the index is over 1.15 male or over 1.11 female, an overweight or obese condition can usually be assumed. In extremely thick-framed, muscular individuals, however, the index may be as high as 1.20 male or 1.16 female without superfluous adiposity being present. Contrariwise, in extremely slender-framed individuals, the index may be as low as .80 male or .84 female without the person necessarily being "underweight".

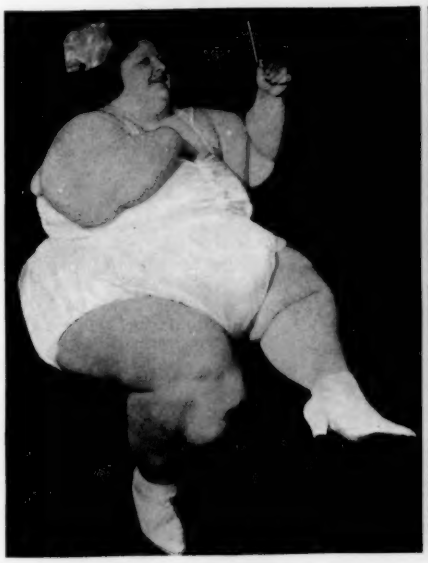
Expressed as a formula, the Index of Body Build (relative girth or breadth) equals:

$$\frac{\sqrt{\frac{\text{Weight (pounds)}}{\text{Height (inches)}}}}{\text{Height (inches)}} \times \begin{matrix} 44 \text{ male;} \\ 46 \text{ female.} \end{matrix}$$

In metric units it is:

$$\frac{\sqrt{\frac{\text{Weight (kg.)}}{\text{Height (cm.)}}}}{\text{Height (cm.)}} \times \begin{matrix} 2.65 \text{ male;} \\ 2.77 \text{ female.} \end{matrix}$$

The reason for the difference in the above divisors is that, *for a given stature,* the perfectly-proportioned man is about 4.5 per cent greater in girth and breadth, generally, than the perfectly-proportioned woman. Accordingly, to yield in the individual case an index proportionate to the differing girth/height standard in the two sexes, the divisor must differ by 4.5 per cent.



VIEWS OF THE LATE MRS. RUTH G. PONTICO SHOWING FAT DISTRIBUTION

Miles Darden, whose weight was over 1000 pounds, had an index of only 1.65, since he was a giant in height as well as in bulk, standing 7 feet 6 inches. To have been as large in girth proportionately to his height as Mrs. Pontico, he would have had to weigh the incredible amount of 2000 pounds! Or, to have been equivalently bulky at his weight of 1000 or so pounds, his height would have had to be not more than an even six feet.

In William Campbell, whose weight was 728 pounds and height 6 feet 3 inches, the index is 1.83. In Daniel Lambert, who was 739 pounds and 5 feet 11 inches, the index is 2.00. In T. A. Valenzuela, who was the same height as Lambert, it is from 2.01 to 2.14, depending on the increase in his weight from 745 pounds to possibly 850. In Joseph Raggio, who was 701 pounds and 5 feet 8 inches, the index is 2.08. In Granville Hall, who was 700 pounds and only 5 feet 5 inches, the index is 2.22.

Thus, *in relation to stature,* it would appear that Mrs. Pontico has greater bulk and weight (and implied larger girth measurements) than any other person, male or female, of whom the stature as well as the weight has been recorded. Her only close competitor in this respect is, possibly, the colored woman, quoted by Gould and Pyle, as having weighed 850 pounds. This subject would have had to be no greater in height, however, than 5 feet 7½ inches in order to have been as bulky, proportionately, as Mrs. Pontico.

In view of these extremely-obese individuals and their relative-girth indices, it is perhaps safe to say that an index of 2.35 male or 2.46 female would represent the maximum possible obeseness, or "bulkiness", relative to height. Of course, the relating of girth (or horizontal breadth or depth) to height can be done in various ways, either by using a direct girth measurement or measurements, or by deducing the general girth from the square root of the weight per unit of height, as herein formulated.

Various authors have, in the aggregate, introduced a great variety of indices of body-build, each designed for a particular purpose but some of which are unnecessarily complex and unwieldy. Hence the presentation and use in this paper of the easy-to-comprehend, yet appropriate and accurate index of body build, previously described.

MRS. PONTICO'S PHYSIQUE AND MEASUREMENTS

Now, to tell of our present subject's unique physical makeup, and of how her life is necessarily modified to conform with it. Her occupation,

naturally, is professional "fat lady"; and in this profession she has exhibited for the last several years with the Royal American Shows, a traveling carnival that tours each season over most of the eastern, southern, and mid-western states.

Like most extremely fat individuals, Mrs. Pontico was "always that way", and even at the early age of ten years tipped the scales at 300 pounds. Her weight at birth was 16 pounds, and at one year 50 pounds—each being more than double the weight of the average child of that age. Her tendency to huge size was inherited from the maternal

TABLE 1

Comparative bodily measurements of Mrs. Ruth Pontico (A) and average-sized woman of the same stature (B)

MEASUREMENT	A		B		$\frac{A}{B}$
Weight	772.5 lbs.	(350.4 kg.)	132 lbs.	(60.2 kg.)	...
	Inches	*Centimeters*	*Inches*	*Centimeters*	
Height, standing	65.5	(166.4)	65.5	(166.4)	...
Height, sitting	36.5	(92.7)	34.4	(87.4)	...
Span, or arm stretch	66.0	(167.7)	65.5	(166.4)	...
Girth, neck	24.0	(61.0)	12.9	(32.8)	1.86
upper arm (flexed), right	31.5	(80.0)	11.4	(29.0)	2.76
upper arm (flexed), left	34.5	(87.6)	11.2	(28.5)	3.08
upper arm (straight), right	30.0	(76.2)	10.4	(26.5)	2.88
upper arm (straight), left	34.0	(86.4)	10.2	(25.9)	3.33
forearm, right	18.75	(47.6)	9.8	(25.0)	1.90
forearm, left	19.0	(48.3)	9.6	(24.5)	1.97
wrist, right	10.25	(26.0)	6.3	(16.0)	1.63
wrist, left	10.0	(25.4)	6.2	(15.8)	1.61
chest, at armpits (passive)	81.5	(207.0)	34.0	(86.5)	2.39
waist	76.5	(194.3)	26.6	(67.6)	2.87
hips (and, in A, abdomen)	91.0	(231.1)	38.2	(97.1)	2.38
thigh, right	49.0	(124.5)	22.4	(57.0)	2.18
thigh, left	47.5	(120.7)	22.4	(57.0)	2.12
knee, right	37.0	(94.0)	14.4	(36.7)	2.56
knee, left	34.5	(87.6)	14.4	(36.7)	2.39
calf, right	29.75	(75.6)	13.9	(35.3)	2.14
calf, left	29.5	(74.9)	13.9	(35.3)	2.13
ankle, right	14.5	(36.8)	8.5	(21.7)	1.70
ankle, left	14.25	(36.2)	8.5	(21.7)	1.67

side of her family especially, as her mother, who was also a professional fat lady, weighed at her heaviest over 720 pounds and was six feet tall. Her father, too, while light by comparison, was actually a large man, being about six feet in height and weighing over 250 pounds.

Mrs. Pontico, although her married name is Italian, is predominantly of American ancestry, her parents, grandparents, and great grandparents all having been born in or near the state of Indiana. It was there, too, that she was born, on February 8, 1904. Her bodily measurements on April 10, 1939, at the age of 35, are given in the first and second columns of Table 1. For comparison, in the third and fourth columns, are the measurements of a perfectly-proportioned young woman of medium build, of the same stature. These "perfect" measurements are based on a previous thesis by the author (2). Lastly, in the right-hand column, are shown the ratios of each of Mrs. Pontico's girth measurements to those of the control subject. Fig. 1, drawn to scale, gives a graphic representation of the measurements of these two individuals.

It is hardly necessary to call attention to the hugeness of Mrs. Pontico's proportions, as shown above. Since the size of a person's girth measurements in general is governed by the amount the person weighs[3] *in ratio to his or her height,* it is probable that our subject, with a weight of 11.8 pounds for each inch of her height, has nearly, if not actually, as large girth measurements as anyone, man or woman, who ever lived. Even the gigantic Miles Darden is not quite her equal in this respect, for even if we credit him with a weight of 1020 pounds,[4] his great height of 90 inches would give him the slightly lesser weight per inch of height of 11.3 pounds. Of our other listed subjects, of known height, only one, the Mexican giant T. A. Valenzuela, surpasses Mrs. Pontico's weight/height of 11.8 pounds. If Valenzuela, at the time of his death, actually weighed 850 pounds, his weight/height would have been 11.97 pounds. Another possible exception, again, is the Negro woman who allegedly weighed 850 pounds; but since her height

[3] This is strictly true only if it be assumed that the specific gravity of the body is constant. Actually, however, this fluctuates among different individuals; and there are other factors, such as the *proportions* (relative girths) of the body, comparative *lengths* of the trunk and extremities, and relative weights of the *skeleton* and *soft tissues,* all of which make it impossible to predict the exact volume (and hence, general *girth*) of an individual from his or her body weight.

[4] His weight, in one account, is given as 1040 pounds, presumably in ordinary clothes.

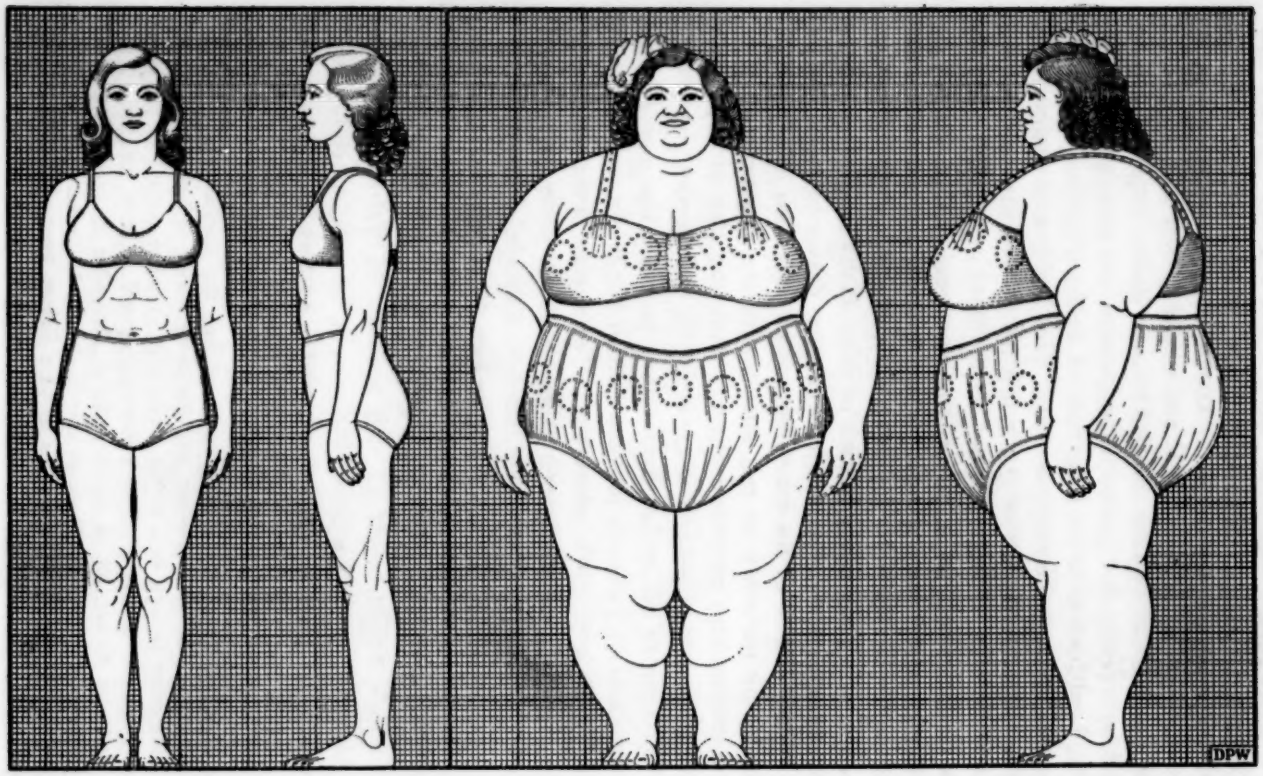


FIG. 1. SCALE DRAWING BY THE AUTHOR SHOWING THE LATE MRS. PONTICO "ARCHITECTURALLY" COMPARED WITH AN AVERAGE-SIZED, WELL-PROPORTIONED YOUNG WOMAN OF THE SAME HEIGHT, WEIGHING 132 POUNDS

The background of the drawing is divided into ½-inch squares.

was not recorded, there is no way of knowing what she weighed per inch of height.

It may here be opportune to point out that the famous Daniel Lambert was credited on his tombstone with having had a measurement of 9 feet 4 inches (!) "round the body" and 3 feet 1 inch "round the leg" (calf). These, for Lambert's weight per inch of height of 10.4 pounds, are impossibly large measurements, since they surpass by a considerable margin those of Mrs. Pontico, who would be expected to have, from her 11.8-pound weight/height, girth measurements about six per cent *larger* generally than one of Lambert's build. T. A. Valenzuela, who had the same height and (when he weighed 745 pounds) approximately the same weight as Lambert, reasonably claimed a waist (or maximum body girth) of 89 inches; and his calves, as could be estimated from his photographs, were probably not more than 28 inches in girth. Thus, Lambert's alleged girth measurements appear to be in the same class as other fallacies of size, longevity, etc., which, often founded upon mere heresay, recollection, or misinterpretation, are handed down as facts by "historians" rather than first investigated by trained scientific observers in their special fields.

Another point of interest in connection with the alleged weight of old-time fat persons is that, in a number of instances, their weight, being ascertained for the final time upon their burial, included the weight of their *coffin!* This circumstance, while usually explained in the original biographical account, was often overlooked in subsequent abstracts from it. The result was that the bodyweight of such coffined persons was commonly overstated by 100 pounds or more!

Such consideration should only strengthen the position of Mrs. Pontico as an example of "weight", and increase the value and dependability of the accurately-taken, living measurements of her presented here.

MRS. PONTICO'S DAILY LIFE

In respect to Mrs. Pontico's extreme size, the question arises: "How does she manage to get around"? Her physical activity is naturally somewhat restricted. In 1935, she had pneumonia, during which she lost some 200 pounds in weight. The redistribution of weight attendant to this loss put a strain on her spine; and a year of complete rest was necessary for her health and the 200 pounds to be regained. The spine, however, remained in a weakened condition, and she now does no more walking than is necessary. Nevertheless, at her home in Florida, she manages every few days to get around the extensive grounds, by walking

The background of the drawing is divided into ½-inch squares.

a bit and then resting. She even climbs the stairs to the second floor of her home once or twice a day—and the stairs are of the usual height, not specially reduced.

The surprising thing is that anyone her size should be able to get about at all, since every movement, considering the weight of the body and limbs, becomes veritably a feat of strength. In all probability, duly granting that most of her weight consists of fat, the muscles underlying that fat must be very much stronger than those of the average woman.

As for procuring clothes, hats, shoes, and other wearing apparel ready-made, Mrs. Pontico finds that it is simply out of the question. The largest women's hat size made is for a head measuring 25½ inches in girth, and our subject's head is slightly larger than that. The size of gloves ample to accomodate her well-padded hands is indeterminate, since the largest size handled in stores is size 8, and that is not large enough. Her foot length is size 5½ (or about 244 mm., weighted), but because of the extreme width of her feet (about 102 mm.), she must buy shoes of excessive length in order to get the necessary width. The size she now wears is 8½ in EEE width; yet even this size, while much too long, is hardly of sufficient width. She says she has had shoes made to order, but never found them satisfactory either, for various reasons.

While one might reasonably suppose the amount of food consumed by our subject to be enormous, actually it is only about one-half again the amount an ordinary person eats. Therefore, in proportion to body weight, she consumes only about one-third as much as an average-sized person. Her hours of sleep, too, are about the same as those of most people. When on tour, however, she necessarily retires quite late, being on exhibition each day from early afternoon until midnight. Show season, as usual, is from spring until fall.

CAUSE OF EXTREME OBESITY

A most pertinent question, of course, is what causes such extreme obesity as that possessed by Mrs. Pontico and other professional fat people. A generation ago, before medical science had really explored the problem, it was thought that most if not all overweight persons were simply victims of that common combination—overeating and lack of exercise. Today, however, it is known that while many ordinary cases of overweight may be due to this cause, the really extreme cases—those, say, in which the individual weighs 300 pounds or more—are due primarily to a disturbance of the balance between fat absorption and fat storage. This imbalance, in turn, has until recently been attributed almost entirely to a faulty working of the glandular system—especially to that small but important part containing the pituitary gland.

It is true that certain cases of "pituitary obesity" may result from injuries to the brain, either following a basal fracture or in the course

of a growing brain tumor in or near the pituitary. However, prominent endocrinologists who have long studied the problem feel that the cause of most obesity—even such extreme cases as the circus fat ladies—is to be found, not directly in the glandular system, but rather in those parts of the metabolic apparatus itself which have to do with the stimulation of appetite and the absorption of fat-forming food elements.

Then, of course, there are hereditary as well as constitutional factors; and many a child is or becomes fat and overweight simply as a result of his parents and grandparents having been the same way. In such cases the factor inherited would appear to be a metabolism that was unusually efficient in the *producing and storing of fat* from the assimilated materials. Dr. Charles B. Davenport (3), in an extensive study of the hereditary factors of body-build, found among other things that "the offspring of two fleshy parents are twice as variable (in build) as those of slender parents". Thus, one possibility in a child coming from heavy-built parents is that the child may grow to be even fatter and heavier than either of its parents.

In the case of Mrs. Pontico it is evident that every possible fat-favoring factor must have combined to produce her unique bulkiness of figure. First, both her parents were large and fat—her mother extremely so—and this tendency to obesity they transmitted, intensified, to their daughter. Second, it is probable that our subject, from the time she was born, had an exceptionally large appetite and likewise a constitution (metabolism) that was abnormally efficient in producing and storing fat. Of her, indeed, it might appropriately be said, "Everything she eats turns to fat".

We have mentioned previously that, in proportion to body weight, Mrs. Pontico consumes only about one-third as much food as an average-sized person. But this is a misleading comparison. It should be remembered that our subject's food intake should not be based on her weight, since by far the greater part of this is fat, and fat needs no food for its maintenance! Therefore, if she would cut her present food consumption in half and "live off her fat", it is possible (though by no means certain) that she would lose weight. However, to lose *much* weight, even if this could be accomplished, would be inimical to her professional standing, since her fame and livelihood depend on her keeping as fat as possible.

SUMMARY

The fourfold purpose of this paper is (1) to bring together and review some of the more remarkable recorded cases of human obesity; (2) to select from these cases the individual extreme; (3) to present a formula or "index of relative obesity" whereby this and other individuals may be rated; and (4) to cite the bodily measurements and general physical history of the most obese person thus determined. The main features and findings of the study are as follows:

1. In a survey of the medical, historical, and journalistic literature on extraordinary instances of obesity, the author found only 16 cases in which the person weighed 700 pounds (317 kg.) or more. Of these cases, 10 were men and 6 were women. The heaviest man weighed more than 1000 pounds (454 kg.); the heaviest woman reputedly 850 pounds (386 kg.).

2. In the scientific classification of obesity—that is, the *relative degree* of fatness — height as well as weight must be taken into account, so that the classificatory index shall express the general width or girth of the body *relative* to the height. An index of this kind, for expressing in comparable units the body build of any person, whether fat, thin, or any degree between, is herein presented and described.

3. Judged by the latter index, the fattest human being known at the present time, and possibly of all time, is our subject who weighs 772½ pounds (350.4 kg.) at a stature of only 5 feet 5½ inches (166.4 cm.). This ratio of weight to height endows Mrs. Pontico with girth measurements which, in general, are 2.41 times as great as those of a woman of medium build of the same height. In none of the other 15 listed subjects, of known height here studied, is the "index of relative obesity" higher than 2.22.

4. Details of Mrs. Pontico's physical history and problems of her daily life are presented, as interesting addenda to the list of her bodily measurements. A brief commentary on the hereditary, constitutional, and pathologic *causes* of extreme overweight is also given.

5. From an anthropometric study of Mrs. Pontico and other persons of extreme fatness, it may be inferred that an index of 2.35 male or 2.46 female, derived by the author's formula, would represent the maximum possible obeseness, or bulkiness, relative to height.

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AMERICAN INDIAN CRANIA WITH LOW VAULTS

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DESPITE the publication of a considerable amount of craniometric data on the Indians of North America, there have been relatively few attempts at syntheses. The earlier investigators contented themselves in searching for characteristics common to all American Indians and noting considerable differences between tribes and larger ethnic groups. Both Morton (1839) and Meigs (1866) indicated that there were low-vaulted skulls among the Dakota and some other tribes, but because of the smallness of their samples were not able to draw broader conclusions concerning the distribution of this trait. Roland B. Dixon (1923) in *The Racial History of Man* attempted a synthesis in which he utilized vault height (length-height index) in the differentiation of his types, and indicated its distribution over the continent. He divided his crania into high- and low-vaulted ones, assuming the intermediate forms to be blends of the extreme forms, and separated all of his material into eight arbitrary types on the basis of two classes each of the length-breadth, length-height, and nasal indices. But, as a whole, it may be said that Dixon considered head height of but minor importance—disregarding it in his distribution maps in which he, for example, combined the two long-headed and broad-nosed types—and left many of his contentions unsupported by metrical data. Stewart (1940) points out in addition that in basing his type classification on both crania and data on the living, Dixon neglected most of the evidence derived from measurements of the height of the braincase, favoring the measurements on the living. This was partly due to the fact that in the living there is no measurement comparable to basion-bregma height.

With the publication of the *Catalogue of Human Crania* . . . (1924, 1927, 1931, and 1940) Hrdlička presented a clearer picture of the types of American Indians and the distribution of low-vaulted groups.

Although the pooling of some of these groups was on the basis of similarity of type, disregarding archaeological and time elements, the results in many instances turned out about the same as when these factors have been taken into consideration. Thus when all the crania from one of the archaeological horizons in Illinois were separated from another in the same locality, the later one yielded only skulls of his Algonkin type which metrically and morphologically checked closely with some of his groupings by type and state. In addition to giving the basion-bregma height, Hrdlička employed the mean height index, 100 $H/(L+B/2)$, in preference to the length-height and breadth-height indices in the description of the height of the braincase. Recently Stewart (1940) summarized these and other data on relative head height of American Indian groups, presenting the results in a table and a distribution map. By dividing the list of mean height index values for twenty-nine American Indian series, arranged in descending order, into two groups Stewart presented supporting evidence for Hrdlička's separation of some of the low-vaulted Athapascan, Siouan, Caddoan, and Shoshonean groups.

Attention should be called here to the fact that on the basis of this division of the mean height index alone the intermediate values for the Huron series disappears in the eastern high-vaulted group, and a number of low values, as those of various series from southern California, group themselves with those of the northern Plains tribes which represent a different type altogether. In the latter respect the distribution map, though correct as to the index, gives an erroneous impression as far as continuity of type is concerned.

During my stay at the U. S. National Museum, while describing a number of Fort Ancient Aspect series, the question of possible Siouan affiliations of one or all these series arose, and I became interested in the morphological characters that differentiate various Siouan-speaking groups from their neighbors. In this investigation I noticed that not all low-vaulted crania exhibit low basion-bregma values for the same reasons, and decided to attempt a metrical analysis of this dimension into its components in order to determine just what constitutes a low or a high vault in a number of representative American Indian series. The results of this study present data, which, it is believed, can be utilized for a future synthesis.

There are four possible explanations for a low basion-bregma height: (1) that we are dealing with a small skull, and therefore not

with a relatively low skull at all; (2) a skull with a truly low vault—a skull in which the upper component of the height is short; (3) a skull with a flat base;[1] and (4) a skull exhibiting a combination of low vault and flat base. This, of course, disregards variations in position of the anterior edge of the foramen magnum where basion is located, but this difference is rarely more than 3 mm. either way of a plane through basion and two points on the surface of the occipital bone laterally to the occipital condyles.

In order to express these differences in the components of vault height metrically, I worked from the individual median sagittal contours on which the two superimposed poria and the left orbitale were marked so that the ear-eye plane could be indicated. The ear-eye plane cuts the basion-bregma height into a long upper and a short lower segment, roughly separating the vault from the base. This is indicated in Fig. 1, which shows a San Carlos Apache skull in which the lower segment is short and a Fort Ancient Aspect skull in which it is relatively long.

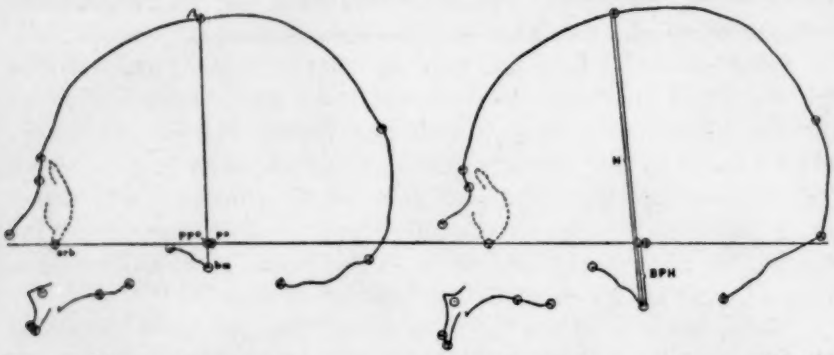

FIG. 1. MEDIAN SAGITTAL CONTOURS OF A SAN CARLOS APACHE SKULL (USNM 228,362) IN WHICH THE LOWER SEGMENT OF THE BASION-BREGMA HEIGHT IS SHORT AND A FORT ANCIENT ASPECT SKULL (BLM 1) IN WHICH THIS SEGMENT IS LONG

The measuring points — basion (ba), bregma (b), orbitale (orb), porion (po), and projected porion (ppo) — are located on the first, and the measurements — basion-bregma height (H) and basion-projected porion height (BPH) — on the second diagram.

[1] That the declination of the pars basilaris differs is well known and Oetteking (1924, 1930) examined a San Miguel Island and a number of Northwest Coast series for this difference. The basion-projected porion distance, taken up below, indicates approximately the same condition as the angular measurement, except that it has the advantage that it can be expressed as part of the total vault height in the index of flatness of the cranial base.

For convenience the basion-bregma height is designated H and the basion-projected porion height BPH in the following tables. The index, the product of dividing the lower component by the total basion-bregma height, which can be called the index flatness of the cranial base, is designated by 100 BPH/H. When the means for these three values of a certain series are placed side by side one can get a fair idea of the absolute and relative component values of the basion-bregma height.

The groups selected to illustrate differences in the basion-bregma height are seven series of male crania from various parts of the

TABLE 1

Aleut, adult, male, 24, U.S.N.M. Collections

CAT. NO.	H	BPH	100 BPH/H
17,479	130	19	14.62
17,485	128	13	10.16
225,266	127	20	15.75
242,848	129	19	14.73
242,849	129	23	17.83
242,863	124	19	15.32
242,868	121	15	12.40
242,869	131	17	12.98
242,871	123	14	11.38
242,875	133	20	15.04
242,880	132	16	12.12
242,882	128	21	16.41
242,900	122	11	9.02
242,908	121	12	9.92
242,909	134	18	13.43
242,910	125	19	15.20
242,912	127	17	13.39
242,915	126	13	10.32
242,922	128	16	12.50
242,924	129	19	14.73
242,930	125	17	13.60
242,940	128	17	13.28
242,943	123	21	17.07
243,977	125	18	14.40

continent,[2] and range in time from the earliest pre-ceramic horizon from which crania are available to skulls of historic Indian tribes.[3]

The Aleut series was chosen as representing a physical type, characterized by a low vault, that is found widely scattered over the northwestern part of the continent. It probably was the last type of the yellow-brown or Asiatic subspecies of Man to make its appearance in the New World. This series of twenty-four crania, the measurements of which are given in Table 1, seems to be rather homogeneous.

The series of sixteen Apache skulls (Table 2) is made up of specimens representing nine tribal subgroups, the largest of which, the San Carlos Apache, comprises four crania. Despite the somewhat scattered origin of the individual specimens, the series as a whole can

TABLE 2

Apache, adult, male, 16, U.S.N.M. Collections

CAT. NO.	H	BPH	100 BPH/H
225,076	131	23	17.56
225,094	128	17	13.28
225,102	127	14	11.02
228,359	132	16	12.12
228,360	129	19	14.73
228,362	123	11	8.94
228,363	131	13	9.92
243,485	126	19	15.08
243,487	133	19	14.29
243,786	132	19	14.39
243,856	127	15	11.81
243,857	129	14	10.85
243,860	124	15	12.10
243,871	120	12	10.00
243,874	132	17	12.88
243,876	132	18	13.64

[2] In this place I should like to express my gratitude to Mr. Frank M. Setzler, Dr. Aleš Hrdlička, and Dr. T. D. Stewart of the United States National Museum, and to Mr. Clifford Anderson, owner of the museum at Fort Ancient, for their kindness in permitting measurements to be taken on cranial material in their charge.

[3] Employing von Eickstedt's terminology (1934) with my own modifications, four of the varieties of the Asiatic subspecies of Man found in North America are represented: the Pacifid race by the Aleut and Apache series; the Sylvid race by the Anderson Village, the Indian Knoll, and the Huron samples, which illustrate three different types; the Centralid race by the Florida series; and the Prairid race by the five Dakota tribal groups.

be pooled without hesitation, and like the Aleut series, represents a physical type of the same (Pacifid) race. The Apache are an Athapascan-speaking family of tribes that is believed to have migrated from the Canadian Northwest and entered the Southwest around 1300 A.D., or somewhat earlier. Similarity in physical type of the two groups would be expected, although, as with the Navaho who also speak Athapascan, this does not necessarily follow. In basion-bregma height and basion-projected porion values, as well as in the index of flatness of the cranial base, the means of the San Carlos Apache (H, 129 mm.; BPH, 15 mm.; 100 BPH/H, 11.43) are very close to the means of the pooled Apache series, for which the respective values are 128.5 mm., 16 mm., and 12.66; and the former appear to approach the Aleut series the closest in most morphological attributes.

The Anderson Village series (Table 3) of twenty undeformed adult males represents a sample of the earlier Fort Ancient Aspect

TABLE 3

Anderson Village, adult male, 20, Anderson Collection

CAT. NO.	H	BPH	100 BPH/H
41,517	143	25	17.48
41,521	141	26	18.44
41,538	140	28	20.00
41,550B	139	30	21.58
41,563A	144	30	20.83
U1	134	21	15.67
U2	140	26	18.57
L1	141	29	20.57
4	139	18	12.95
6	131	25	19.08
39	142	28	19.72
53	141	26	18.44
56	135	23	17.04
61	138	26	18.84
78	142	24	16.90
83	140	25	17.86
91	142	30	21.13
93	142	27	19.01
95	152	26	17.11
103	140	22	15.71

people which may very well have been the ancestors of the Shawnee. This site in Warren County, Ohio, can be roughly dated as having been occupied sometime between 1560 and 1620. Only one rather homogeneous cultural horizon is encountered at the site. Unlike the Madisonville people of the same culture, the Anderson Village series represents the dolichocranial, hypsicranial physical type characteristic of the majority of the Central Algonkins.

TABLE 4

Indian Knoll series, adult, male, 29, U.S.N.M. Collections

CAT. NO.	H	BPH	100 BPH/H
290,015	142	24	16.90
290,016	144	32	22.22
290,017	136	21	15.44
290,018	136	27	19.85
290,020	142	26	18.31
290,021	135	26	19.26
290,023	134	22	16.42
290,025	136	18	13.24
290,026	132	24	18.18
290,029	133	20	15.04
290,035	140	23	16.43
290,036	139	24	17.27
290,037	145	28	19.31
290,038	136	23	16.91
290,039	140	26	18.57
290,040	138	25	18.12
290,041	136	23	16.91
290,042	135	19	14.07
290,043	141	24	17.02
290,047	144	24	16.67
290,052	141	27	19.15
290,054	134	25	18.66
290,057	138	25	18.12
290,059	139	27	19.42
290,061	141	29	20.57
290,062	140	24	17.14
290,069	135	25	18.52
290,070	142	28	19.72
290,073	138	24	17.39

The Indian Knoll crania from Ohio County, Kentucky, were included in this list because they represent the pre-ceramic people who were responsible for the extensive shell middens along the rivers of western Kentucky, Tennessee, and northern Alabama. Hrdlička (1927), who first described this series, assigned it to his Algonkin physical type. All specimens in this collection of twenty-nine skulls can safely be classified as of the same type. The individual measurements are given in Table 4.

The thirteen Huron crania (Table 5) are from southeastern Ontario and all but two are typical of the eastern long-headed Sylvids. The exceptions are USNM No. 239,104 and 239,109 which exhibit a number of characteristics frequently encountered in skulls from the later archaeological horizons in the southeastern states. In New England, Ontario, and New York State, a relatively more low-vaulted variant of the Sylvid race is encountered, and this forms the basis for the inclusion

TABLE 5

Huron, adult, male, 13, U.S.N.M. Collections

CAT. NO.	H	BPH	100 BPH/H
228,900	136	22	16.18
239,104	143	25	17.48
239,105	137	25	18.25
239,106	129	18	13.95
239,107	134	24	17.91
239,108	134	20	14.93
239,109	137	28	20.44
239,110	132	23	17.42
239,111	147	25	17.01
239,112	141	23	16.31
239,113	136	19	13.97
272,242	135	23	17.04
272,246	135	21	15.56

of the Huron series. The two skulls that are not entirely typical of the group have been retained, as one usually encounters a small percent of these high, rugged, and less long-headed skulls in Iroquois samples.

The Florida sample is composed of eight specimens from the east coast and eight from the Gulf coast. Both sub-groups represent the

same historically late, heavy, high-vaulted moderately brachycranial Centralid race characteristic of the Indians of northern Florida and most of the Mississippi horizons of the southeastern states. The homogeneity of the pooled sample is reflected by the means of the two measurements and the index of the sub-groups, which are given as sub-totals in Table 6.

TABLE 6

Florida crania, adult, male, 16, U.S.N.M. Collections

CAT. NO.	H	BPH	100 BPH/H
242,619	138	21	15.22
242,621	149	22	14.77
242,622	141	29	20.57
242,624	137	20	14.60
242,629	143	24	16.78
242,662	143	24	16.78
242,683	145	26	17.93
292,778	148	21	14.19
East coast	143	23	16.36
225,075	136	21	15.44
242,653	146	31	21.23
242,684	147	25	17.01
243,691	140	21	15.00
292,775	149	20	13.42
300,118	136	20	14.71
306,701	143	25	17.48
315,004	142	26	18.31
West coast	142	24	16.57

The Sioux group, finally, is composed of crania of individuals of five tribes: Brulé, Oglala, Sisseton, Teton, and Yankton—all subdivisions of the Dakota family of the Siouan stock. These five tribal divisions have been included because they represent the fairly homogeneous low-vaulted physical type (Prairid race) characteristic of a large percentage of the individuals in tribes of the northern Plains.

Following the table of individual measurements (Table 7) there is a table of means to indicate tribal variability within the racial grouping. Morphological observations and measurements indicate that pooling of the measurements of the tribal series is permissible, and the means listed in Table 8 bear this out.

TABLE 7

Sioux, adult, male, 30, U.S.N.M. Collections

CAT. NO.	H	BPH	100 BPH/H
225,220	127	20	15.75
225,228	133	19	14.29
225,238	133	17	12.78
225,245	129	14	10.85
243,378	122	13	10.66
243,703	132	19	14.39
243,707	130	23	17.69
243,709	130	19	14.62
225,062	124	12	9.68
225,235	126	22	17.46
243,242	124	18	14.52
243,244	123	17	13.82
243,245	129	22	17.05
243,247	130	17	13.08
243,248	132	20	15.15
243,251	130	15	11.54
243,710	132	27	20.45
243,711	128	21	16.41
243,721	128	19	14.84
225,217	129	17	13.18
225,478	130	23	17.69
243,368	126	20	15.87
225,063	128	16	12.50
243,340	124	15	12.10
243,341	128	22	17.19
243,664	128	22	17.19
243,332	130	25	19.23
243,334	126	19	15.08
243,336	129	23	17.83
243,337	128	19	14.84

TABLE 8

Means for Dakota tribes

TRIBE	H	BPH	100 BPH/H
Brulé (8)	129	18	13.88
Oglala (11)	128	19	14.91
Sisseton (3)	128	20	15.58
Teton (4)	127	19	14.74
Yankton (4)	128	21	16.74

Table 9 gives the number, range, mean and its probable error, and the standard deviation and its probable error for basion-bregma height, basion-projected porion height, and the index of flatness of the cranial base for the seven American Indian samples. Comparing these statistical constants the relationships between the groups regarding basion-bregma height become clear at a glance, and lead one to the following conclusions:

1. Among the Aleut, Apache, and Sioux, the lowness of the cranial vault is for the most part due to a short basion-projected porion distance, i.e., a flat base, although the Sioux group tends toward being more intermediate, probably due to Sylvid admixture. The mean basion-bregma height for these three series is around 128 mm., the basion-projected porion height around 17.5 mm., and the index of flatness of the cranial base around 13.7, that is, the basion-projected porion distance is only 13.7 percent of the total height. If one considers the means with average standard deviations of 3.80 for basion-bregma height, 3.01 for basion-projected porion height, and 2.15 for the index of flatness of the cranial base in mind, it will be seen that there is comparatively little overlapping between these three series and the other samples.

2. In the dolichocranial, high-vaulted (mean, 140.30 mm.) Fort Ancient Aspect skulls from the Anderson Village site, the basion-projected porion value (mean, 25.75 mm.), as well as the value for the index of flatness of the cranial base (mean, 18.35), are the highest of the seven groups considered here. These crania exhibit the most downward projecting, or least flat, bases, and the most equal proportioned height components. The Indian Knoll series exhibits a little

TABLE 9

Statistical constants for seven American Indian groups

	ALEUT	APACHE	ANDERSON VILLAGE	INDIAN KNOLL	HURON	FLORIDA	SIOUX
NUMBER	24	16	20	29	13	16	30
H, range	121—134	120—133	131—152	132—145	129—147	136—149	122—133
H, mean	127.00±.49	128.50±.63	140.30±.62	138.34±.43	136.62±.85	142.69±.73	128.27±.35
H, sigma	3.55±.35	3.71±.44	4.10±.44	3.47±.31	4.55±.60	4.32±.52	2.88±.25
BPH, range	11—23	11—23	18—30	18—32	18—28	20—31	12—25
BPH, mean	17.25±.41	16.31±.52	25.75±.46	24.59±.37	22.77±.50	23.50±.55	19.17±.43
BPH, sigma	3.00±.29	3.07±.37	3.06±.33	2.95±.26	2.67±.35	3.28±.39	3.46±.30
Index, range	9.02—17.83	8.94—17.56	12.95—21.58	13.24—22.22	13.95—20.44	13.42—21.23	9.68—20.45
Index, mean	13.57±.32	12.66±.38	18.35±.32	17.75±.25	16.65±.31	16.47±.38	14.92±.31
Index, sigma	2.36±.23	2.25±.27	2.14±.23	1.99±.18	1.66±.22	2.25±.27	2.49±.22

lower basion-bregma height (mean, 138.34 mm.) and basion-projected porion height (mean, 24.59 mm.), but about the same proportions in height components (mean index of flatness of the cranial base, 17.75), giving supporting evidence for the correctness of classifying these two populations as two types of one race—specifically, the Gooden and Indian Knoll types of the Sylvid race.

3. The somewhat lower-vaulted Huron crania (mean basion-bregma height, 136.62 mm.), which have been classified as a third type (Younge type) of the same long-headed race, are a little shorter in basion-projected porion height (mean, 22.77 mm.) as well as in the upper height component. This represents a proportionate lowness (with an intermediate index of flatness of the cranial base of 16.65) in contradistinction to the lowness of the Pacifid Aleut or Apache vault.

4. The crania of the Centralid Florida series, which are characterized by considerable vault height (mean basion-bregma height, 142.69 mm.), exhibit almost the same proportions of height as the lower Huron crania (index of flatness of the cranial base of 16.47 and 16.65, respectively). In absolute dimensions, the lower segment (mean basion-projected porion height, 23.50 mm.) as well as the upper segment is high.

In conclusion it may be said that in the interpretation of similarity or various degrees of dissimilarity in basion-bregma height it is advisable to examine the components that make up this dimension. If these segments are not actually measured one should at least keep these differences in mind in order to avoid errors despite seeming indications of close relationship offered by certain kinds of metric data. The basion-bregma measurement should by all means be retained, as, despite its short-comings as a diagnostic criterion between certain American Indian groups, it constitutes an important expression of differences between others.

The index of flatness of the cranial base sets off at least one Prairid and perhaps two Pacifid types from two Sylvid and one Centralid type, and aids in the assigning of the Younge type with its intermediate basion-bregma height value to the Sylvid race. On the other hand, it does not help in distinguishing between Sylvids and Centralids or between Prairids and Pacifids, but may be of some value in differentiating some of the low-vaulted California Indian groups from the Pacifids and Prairids.

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SOMATOLOGY OF THE SCHIZOPHRENIC PATIENT (*Concluded*)

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BODY BUILD

WHILE the study of single absolute measurements of an individual is of great value in a constitutional investigation, because reasonably accurate numerical values can be obtained and because these values, in a broad sense, are adequate to demonstrate inter-individual similarities and differences, the organization of these vertical, horizontal, and circumferential somatic dimensions into a structural unit, the habitus of the individual, is of even greater importance. Although no single satisfactory method has yet been devised by which an individual can be typed objectively and accurately on the basis of his quantitative dimensional organization, the impressionistic methods used by trained persons are sufficiently accurate for working purposes to show up any trends in habitus distribution characterizing a given sample. The dual 13-point scale method used here is especially satisfactory in connection with the "pure" types, but it has the drawback that dysplasticity between trunk and legs alone is indicated. The perhaps more important dysplasticities in the organization of the trunk measurements cannot be shown, and individuals of normal trunk organization may be classified as dysplastic on the basis of differences between trunk and legs that seem biologically unimportant.

A distribution of habitus type based on objective criteria with subjective elements at a minimum seemed more desirable than any distribution reached solely by impressionistic typing, and not unattainable. That a well-founded, objective standard which could be generally applied in determining habitus is needed has been widely recognized, but none has been proposed. Kretschmer himself states (1925, p. 5): "Investigation into the build of the body must be made an exact branch of medical science." He contents himself, however, with dividing his material into three types impressionistically and giving the

mean values for a few somatic variables for the individuals of each type. No general principles of variations and similarities (over-lapping) among the types are derived. Other investigators, particularly in Germany, patterning their approach after Kretschmer, divided their material into three groups, impressionistically, determined precise anthropometric values for many basic somatic variables for individuals of each habitus type, noted the broad differences between the types (to be expected since it was on these differences that the impression on which the typing was done was based), but neglected to determine underlying general principles. Among the writers whose work has been outstanding in studying types of habitus *and* anthropometric measurements in relation to schizophrenia may be mentioned Olivier (1922), Henckel (1924), Kolle (1925), Jacob (1923), Wertheimer and Hesketh (1926), Matecki and Szpidbaum (1927) and Burchard (1936). Wertheimer and Hesketh attempted to find an objective method of determining habitus by the use of an index which was found by Farr (1925) and Burchard (1936) to correlate fairly closely with the conventional types determined impressionistically. Burchard (1936) has gone a step further in attempting to differentiate the three types of somatic habitus in respect of what somatic variables each type differs significantly from each other type, and in respect of what somatic variables each type resembles each other type. He concludes rightly that overlapping is so great that no one measurement or index can be used as a reliable substitute for impression type, but fails to develop the possibility he has opened up of distinguishing between the types on the basis of the somatic variables in which they *do* differ, allowing at the same time for overlap where it occurs. Burchard's approach is sound, but he does not carry his implications through to their logical conclusion.

Stevenson (1937), in a discussion of subjective vs. objective methods in constitutional studies, rightly criticizes the efforts to overcome the limitations of a single index by employing a battery of indices. He points out (p. 475) that "The empirically derived numerical formulations thus far proposed have therefore to a large extent merely reflected, and in the last analysis and of necessity only incompletely and inadequately reflected, certain subjectively derived type differentiations of the particular authors concerned." Although he recognizes the difficulties of objectifying the complexities of somatic organization in quantitative terms, feeling that in fact they may be insurmountable,

he concludes (p. 481): "Further progress in the direction of investigating the somatological aspects of human constitution . . . demands more rather than less objectivity. Every effort should be made to conserve and add to the gains already made toward objective concepts and measurements yielding statistically manageable findings."

The absence of any objective criterion for determining habitus is so unequivocally a fact, and the desirability of such a criterion so generally admitted, that it seems impossible at the present time for any serious somatological study to ignore this technical point in methodology. The most obvious approach is, of course, to adopt certain anthropometric measurements which, even though to a certain extent arbitrarily chosen, will, for working purposes, satisfactorily distinguish one type of habitus from another. Since habitus reflects the somatic organization of the individual, no single somatic variable, such as stature alone, or biacromial width alone, or weight alone, will be adequate as the single basis for differentiation. However, if the relative behavior of each somatic variable is recognized qualitatively in progressing from one extreme of the continuously varying scale of somatic type—what is happening to vertical dimensions as horizontal dimensions increase, etc.—and if the respect in which overlapping occurs between the types can be determined, a qualitative formulation of somatic habitus, capable of conversion into quantitative, anthropometric terms, seems possible.

With this point of view, using the material of this study, a set of objective, anthropometric criteria were developed for distinguishing the asthenic, intermediate, pyknic, and dysplastic types from each other, based on similarities and significant differences in anthropometric measurements and indices. The procedure followed in arriving at these criteria has been relegated to an Appendix, since it is essentially the technical development of a more precise tool for the investigation of the schizophrenic psychosis in its constitutional aspects. Reference to the Appendix will orient the reader on the technique which is applied, in addition to the thirteen-point scale already discussed, in determining the somatic organization of the material of this paper.

In Table 14 the distributions of types among the 193 schizophrenic and the 32 non-schizophrenic women as determined by the impressionistic thirteen-point scale method and by the objective technique described in the Appendix are presented. It will be noted that the distributions obtained by these two methods are in fairly good accord,

the most noteworthy difference being in the dysplastic group in the patients, which dwindles remarkably in size when the table of measurements is used for determining habitus. The increase in total number of controls of intermediate habitus, at the expense of asthenics is also a noteworthy finding.

TABLE 14

Percentage distribution of schizophrenic and non-schizophrenic women with regard to type of somatic habitus as determined by the dual 13-point scale method and by the objective criteria based on anthropometric measurements as described in the Appendix

GROUP	ASTHENIC		INTERMEDIATE		PYKNIC		DYSPLASTIC	
	No.	*Percent*	*No.*	*Percent*	*No.*	*Percent*	*No.*	*Percent*
Total schizophrenics								
By 13-point scale	69	35.7	44	22.8	32	16.6	48	24.9
By measurements	75	38.9	58	30.1	37	19.2	23	11.9
Schizophrenics: 40 years of age and under								
By 13-point scale	33	45.8	19	26.3	5	6.9	15	20.9
Controls								
By 13-point scale	11	34.3	15	46.8	5	15.6	1	3.3
By measurements	5	15.6	21	65.6	2	6.3	4	12.5

If the table is considered in some detail, the following points stand out:

1. Every type of somatic habitus is represented in both the schizophrenic and control groups. The asthenic type is most frequent in the schizophrenic group; the intermediate, second; and the pyknic, third. In the control group, the intermediate type is most frequent; the asthenic, second; and the pyknic, third. Since the number of individuals in the control group is small, the probable errors are large, and none of these differences between the two groups is significant by statistical test.

TABLE 15

Compilation of data reported in the literature showing distribution of somatic habitus types in schizophrenic patients

AUTHOR	DATE	LOCUS	NO.	SEX	ASTHENIC	ATHLETIC	ATHLETIC-ASTHENIC	PYKNIC	PYKNIC-MIXED	DYSPLASTIC	UNCLASSIFIED
European											
Kretschmer	1921	Tübingen	175	M-F	46.3	17.7	6.3	1.1	1.7	19.4	7.4
Beringer and Duser	1921	Heidelberg	200	..	...	...	...	...	...	20.5	...
Sioli and Meyer	1922	Bonn	43	M-F	16.3	16.3	34.9	2.3	20.7	9.2	...
Olivier	1922	Düren	64	M	42.2	12.5	4.7	9.4	14.0	12.5	4.7
Verciani	1922	Lucca	74	..	59.3		...	22.9	...	10.8	...
Henckel	1924	Munich	100	M	34.0	25.0	27.0	...	2.0	11.0	1.0
Möllenhoff	1924	Leipzig	100	M-F	15.7	2.9	...	5.0	...	20.7	55.7
Michel and Weeber	1924	Gratz	141	M	74.5		...	18.4	...	6.4	...
Jakob and Moser	1924	Königsberg	168	M-F	54.2		12.5	14.9	...	...	...
Schmidt	1924	Denmark	100	M	40.0	6.0	15.0	9.0	4.0	17.0	9.0
Schmidt	1924	Denmark	100	F	43.0	9.0	10.0	9.0	3.0	17.0	9.0
Van der Horst	1924	Gröningen	69	..	66.0		...	4.0	...	...	...
Kolle	1925	Schwein	100	M	18.0	8.0	14.0	18.0	12.0	4.0	26.0
Kolle	1925	Jena	100	M	11.0	8.0	10.0	21.0	15.0	4.0	31.0
Guber-Gritz	1925	Charkow	251	M-F	34.6	4.3	12.2	12.3	32.4	...	3.5
Wyrsch	1925	Luzerne	192	M-F	42.8	14.6	18.8	9.4	...	8.9	5.7
Weissenfeld	1925	.....	64	..	28.1	65.6	...	5.6	...	...	...
v. Rohden and Grundler	....	Halle	220	M-F		72.3			6.8	15.5	...
v. Rohden	1926	Nietleben	91	M		62.5			13.2	14.4	9.9

TABLE 15 (*Continued*)

TABLE 15 (*Continued*)

European												
v. Rohden	1926	Nietleben	330	M		71.2			8.5		13.3	7.0
Pascal and Vie	1926	.....	119	..	41.2	1.7	...	8.4		...	8.4	40.3
v. Rohden	1926	(Compiled)	3262	M-F		66.0			12.8		11.3	9.9
Matecki and Szpidbaum	1927	Warsaw	100	M	56.0	9.0	1.0	13.0		7.0	17.0	3.0
Perelmann and Blinkow	1929	Baku	60	M	53.4	18.3	20.0	1.7		3.3	3.3	...
Perelmann and Blinkow	1929	Baku	40	F	50.0	7.5	10.0	15.0		5.0	12.5	...
Welti	1930	(Compiled)	5233	M-F	50.3	16.9	...	13.7		...	10.5	8.6
Kisselow	1931	.....	46	M-F	30.4	17.4	...	17.4		...	21.7	13.0
Plattner	1933	Germany	45	..	40.0	33.3	...	26.7		...	...	...
Warstadt and Collier	1935	Germany	34	..	64.2	15.1	...	18.9		...	1.9	...
v. Schwerin	1936	Germany	63	..	22.2	34.9	...	42.8		...	...	...
American												
Wertheimer and Hesketh	1926	Baltimore	25	M	17.4	26.1	34.8	4.3		13.0	...	4.3
Raphael, Ferguson and Searle	1928	Ann Arbor, Mich.	60	M	13.3	15.0	...	5.0		...	10.0	56.6
Burchard	1936	Torrance, Pa.	124	M	46.0	17.7	...	36.3		...	...	...
Terry and Rennie	1938	Baltimore	77	M-F	35.1	15.6	...	9.1		...	28.6	11.7
This paper												
By impression	1939	Baltimore	193	F	35.7	22.8	...	16.6		...	24.9	...
By measurements	1939	Baltimore	193	F	38.9	30.1	....	19.2		...	11.9	...

2. The schizophrenic group shows fewer individuals of the intermediate type than does the control group.

3. The schizophrenic group, by impressionistic typing, resembles the control group in frequency of asthenic type and pyknic type, except that, when the schizophrenic group is corrected for age, making it more comparable to the control group in this respect, the frequency of the asthenic type increases and of pyknic type decreases. This is in accord with the view that habitus tends to modify toward the pyknic type with advancing age. One other explanation suggests itself, however, namely, that individuals of pyknic habitus may less frequently succumb to the schizophrenic process at earlier ages.

3. The schizophrenic group, typed by measurements, exceeds the control group in frequency of occurrence of asthenic habitus and of pyknic habitus. It resembles the control group in frequency of the dysplastic type.

To sum the matter up, it appears that, regardless of whether the individuals are typed by the impressionistic method or according to measurements, the schizophrenic, in comparison with the control group, tends to show the following trends: A higher frequency of asthenic type, a lower frequency of intermediate type, and probably a somewhat lower frequency of pyknic type. Results with regard to the dysplastic type are more equivocal, the schizophrenics showing a higher frequency than the controls, when typed by the 13-point scale (dysplasticity between trunk and leg emphasized), and the same frequency when typed by the measurements (trunk dysplasticity emphasized).

A comparison of these distributions with other distributions of somatic habitus reported in the literature is of interest. Table 15 represents a compilation of the available data on schizophrenic patients, and Table 16 of the data on non-schizophrenic individuals, listed chronologically, with American and European data grouped separately. The divisions, asthenic, athletic, asthenic-athletic, pyknic, pyknic-mixed dysplastic, and unclassified, universally used in Europe have been retained, since so much of the data is European.

Tables 15 and 16, at first glance, are impressive for the apparent lack of uniformity of the findings. The asthenic type of habitus was found, in one sample of schizophrenic patients, to be typical of only 11.0 percent, while in another sample the figure is put at 60.2 percent. Similarly, percentage values for the intermediate type range between 1.7 and 65.6, while the pyknic range is from 1.1 percent to 42.8

percent. This lack of uniformity is probably due to several factors, among them the lack of any objective criteria for typing, and variations between the samples in respect of race and age. The low percentage values for the asthenic and/or intermediate and/or pyknic groups, it will be noted, are given by those writers, Möllenhoff, Kolle, Pascal and Vie, and Raphael, Ferguson and Searle, who place 26.0 to 56.6 percent of their cases under the heading Unclassified, a category which should be theoretically unnecessary when the continuous variation of the types into the other is recognized. The low values for the asthenic habitus given by Sioli and Meyer and by Wertheimer and Hesketh are compensated for by the high percentage frequency in the asthenic-athletic group. The tendency to combine the asthenic and athletic group which appears in both tables, particularly in Table 16 seems biologically unjustified and results in the masking of any shift away from the center toward the lower end of the scale of habitus variation.

Notwithstanding the lack of uniformity in the series of distributions listed in Tables 15 and 16, a certain trend can be found which suggests the answer to the question: do the schizophrenic patients (Table 15) distribute differently in respect of types of somatic habitus than non-schizophrenic individuals? If the twenty-five series of distributions (excluding the present paper) in Table 15 and the eleven series of distributions in Table 16 in which percentage values are given for the "pure" types, asthenic, athletic, and pyknic, are compared to see in what percentage of each series each type occurs in (a) less than 11.0 percent of the series, (b) between 11.0 and 39.0 percent of the series, and (c) in 41 percent and over of the series, Table 17 results.

From this table the following points are to be noted:

1. The finding of the asthenic habitus in 41 or more percent of the cases is reported in eleven (44.0 percent) of the 25 schizophrenic distributions as opposed to only one (9.1 percent) of the 11 non-schizophrenic series. The asthenic habitus *has,* therefore, been found in higher frequency in schizophrenic than in non-schizophrenic individuals.

2. The finding of the intermediate habitus in 41 percent or more of the cases is reported in only one (4.0 percent) of the 25 schizophrenic distributions, in contrast to four times (36.4 percent) in the 11 non-schizophrenic distributions. However, the intermediate habitus in between 11.0 and 40.9 percent of the cases is reported in fifteen (60.0

TABLE 16

Compilation of data reported in the literature showing distribution of somatic habitus type in other than schizophrenic individuals

AUTHOR	MEDICAL STATUS	NO.	SEX	ASTHENIC	ATHLETIC	ASTHENIC-ATHLETIC	PYKNIC	PYKNIC-MIXED	DYSPLASTIC	UNCLASSIFIED
				Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
European										
Gruhle	Normal	118	M	20.3	18.6	0.8	12.7	21.2	11.0	15.3
Perelmann and Blinkow	Normal	300	M	32.3	9.7	10.7	17.3	12.0	1.7	16.3
Perelmann and Blinkow	Normal	40	F	42.5	2.5	5.0	25.0	12.5	2.5	10.0
Perelmann and Blinkow	Criminals	330	M	40.0	13.6	15.8	8.5	10.6	2.1	9.4
Perelmann and Blinkow	Criminals	133	F	30.9	9.0	7.5	26.3	12.0	1.5	12.8
Stern-Grote	Medical dis.	100	M		74.0			24.0	2.0	...
Stern-Grote	Encephalitis	100	M		67.0			31.0	2.0	...
Stern-Grote	Neurol. dis.	100	M		70.0			22.0	8.0	...
Osertsky	Normal	263	M		65.5			21.1	9.2	4.2
Gründler	Paralysis	80	M-F		69.0			20.0	10.0	1.0
Hoffman	Epilepsy	40	M-F		52.5			20.0	5.0	22.5
Michel	Criminals	225	M		86.2			11.1	2.7	...
Schneider	Psychopaths	46	M		65.2			10.9	23.9	...
Bauer	Medical dis.	2010	M		84.9			6.6	...	8.5
v. Rohden (compilation)	Manic-depressive	981	M-F		23.6			66.7	0.4	9.3
v. Rohden	Normal	150	M		78.0			6.7	2.0	13.3
v. Rohden	Normal	225	M		86.2			11.1	2.7	...
Coerper	School children	6000	M-F		45.0			21.5	...	...
Hueck and Emmerich	Medical dis.	1000	M-F		45.2			29.0	0.6	25.2

TABLE 16 (*Continued*)

AUTHOR	MEDICAL STATUS	NO.	SEX	ASTHENIC	ATHLETIC	ASTHENIC-ATHLETIC	PYKNIC	PYKNIC-MIXED	DYSPLASTIC	UNCLASSIFIED
American										
Pearl and Ciocco	Cardiacs	87	M	9.0	71.0	...	20.0	...	...	...
Pearl and Ciocco	Non-cardiacs	50	M	12.0	76.0	...	12.0	...	...	...
Ciocco	Cardiacs	126	F	11.1	61.9	...	27.0	...	...	...
Ciocco	Non-cardiacs	37	F	27.0	62.2	...	10.8	...	...	...
Burchard	Manic-depressive	125	M	28.0	8.8	...	63.2	...	...	...
Burchard	Psychiatric, other than schizophrenic and manic-depressive	151	M	33.1	11.3	...	55.6	...	...	...
This paper										
By impression	Normal	32	F	34.3	46.8	...	15.6	...	3.3	...
By measurements	Normal	32	F	15.6	65.6	...	6.3	...	12.5	...

TABLE 17

Percentage frequency of asthenic, intermediate and pyknic habitus type in 25 series of schizophrenic patients and 11 series of non-schizophrenic patients

PERCENTAGE FREQUENCY IN DISTRIBUTION	ASTHENIC				INTERMEDIATE				PYKNIC			
	25 schizophrenic series		11 non-schizophrenic series		25 schizophrenic series		11 non-schizophrenic series		25 schizophrenic series		11 non-schizophrenic series	
	No.	*Per-cent*	*No.*	*Per-cent*	*No.*	*Per-cent*	*No.*	*Per-cent*	*No.*	*Per-cent*	*No.*	*Per-cent*
10.9 percent and less	0	0	1	9.1	9	36.0	4	36.4	14	56.0	2	18.2
11.0-40.9 percent	14	56.0	9	81.8	15	60.0	3	27.2	10	40.0	7	53.6
41.0 percent and over	11	44.0	1	9.1	1	4.0	4	36.4	1	4.0	2	18.2

percent) of the 25 schizophrenic distributions and in only three (27.2 percent) of the 11 non-schizophrenic distributions. The intermediate type, therefore, as reported in the literature, occurs with essentially equal frequency in schizophrenic and non-schizophrenic individuals, with perhaps some tendency to appear less frequently in schizophrenic than in non-schizophrenic individuals.

3. The finding of the pyknic habitus in 41 percent or more of the cases is reported in one (4.0 percent) of the 25 schizophrenic series, in contrast to two (18.2 percent) in the 11 non-schizophrenic series. Likewise, the pyknic habitus is found in only 10.9 percent or less of the cases in fourteen (56.0 percent) of the 25 schizophrenic series as opposed to two (18.2 percent) in the 11 series of non-schizophrenic individuals. The pyknic habitus, therefore, occurs less frequently in schizophrenic than in non-schizophrenic individuals. The numbers of the dysplastic type are too small to more than suggest conclusions. However, the dysplastic type was present in 11.0 percent or more of the cases in 17 (59.2 percent) of the 25 schizophrenic series, while in only 1

out of 5 (20.0 percent) of the non-schizophrenic series was the frequency this high. That dysplasticity is more common in the schizophrenic group would seem to be indicated.

The concensus of opinion in the literature since Kretschmer essentially corroborates his original formulation (1925, p. 36) "that there is a clear biological affinity between the psychic disposition of the schizophrenes and the bodily disposition characteristic of the asthenic, athletics and certain dysplastics. And vice versa, there is only a weak affinity between schizophrene and pyknic . . . ."

The distributions of habitus type in the 193 schizophrenic women of the present material are likewise in accord with these conclusions. While individuals of all types of somatic habitus may develop a schizophrenic reaction, those at the lower end of the scale of somatic variation, the asthenics, by nature of their constitution, have the greatest exposure to risk, those at the upper end of the scale, the pyknics, the least exposure to risk. Once ill, does the somatic organization of an individual affect the personality aberrations comprising his clinical picture and course? Is an individual of one type of somatic habitus ill in the same way, qualitatively and quantitatively as an individual of another somatic organization? These are the next, and to the clinician the most important, questions to be considered.

PSYCHIATRIC STATUS AND SOMATIC HABITUS

Whether, and in what way, somatic habitus acts as a dynamic factor in the genesis and clinical development of the schizophrenic reaction is the next object of inquiry. The importance of the constitutional factor, in the sense of prepsychotic personality type, in schizophrenic patients has been widely recognized since it was first emphasized by Meyer in his 1906 paper (Hoch, 1910; Kretschmer, 1921; Barrett, 1926; Farr, 1928; Bowman and Kasanin, 1933; Terry and Rennie, 1938; *et al.*). Likewise the importance of the constitutional factor, in the sense of somatic habitus, in the schizophrenic reaction has been widely investigated and generally confirmed, as is evident from the review just completed in the preceding sections of this paper. The further question, however, of what effect, if any, a particular *type* of somatic habitus exerts in determining a particular *kind* of clinical picture has received little attention. The papers of Mauz (1930), Kisselow (1931), Plattner-Heberlein (1932), Vanelli (1932),

and Langfeldt (1937) present pertinent data which will be discussed below.

As the first step in this investigation, it seemed necessary to obtain some sort of a detailed perspective on the clinical characteristics of the group of patients as a whole. The following mimeographed sheet was accordingly prepared and the appropriate data abstracted from the case record of each patient. The patient's prepsychotic personality was evaluated from the history obtained when the patient was admitted to the hospital. The findings on admission mental status examination were used in each case. Course was determined by noting the general trend of the patient's progress from the time of admission to the time when the study was made.

CONSTITUTIONAL STUDY OF PSYCHOSES
Spring Grove State Hospital
Catonsville, Maryland
PSYCHIATRIC DATA

Name..... Case No.....
(Last) (First)

Personality (prepsychotic): syntonic, schizoid, cyclothymic, epileptoid, psychopathic

Mental status:

Rapport: poor, good, stupor, confused, fleeting

Stream of talk and activity: mute, underproductive, normal, over-productive

Affective data: sad, neutral, happy, apathetic, alert, anxious, fearful, perplexed, suspicious, benumbed

Topical data:

Hallucinations (absent, present, visual, auditory, olfactory, gustatory, haptic).

Delusions (absent, present, systematized, non-systematized, somatic, paranoid, reference, influence).

Sensorium defects: absent, present

Orientation: poor, fair, good

Recent memory: poor, fair, good

Remote memory: poor, fair, good

Retention: poor, fair, good

Recall: poor, fair, good

Information: poor, fair, good

Judgment: poor, fair, good

Detection of absurdities: poor, fair, good

Insight: poor, fair, good

Mannerisms: absent, present, postural, facial

Thinking: scattered, preserved, slowed, accelerated

Habit deterioration: absent, present, dress, sphincters

Course: deteriorated, unchanged, improved, well

After all the case records had been abstracted, the assembled material was submitted to biometric analysis, with a view to formulating in as precise and orderly a way as possible the constituent clinical features of the schizophrenic reaction as reflected in this particular sample of patients. The percentage of cases in which defects occur was calculated for each item of the mental status examination as it is conventionally given. These percentages are listed in the left-hand column of Table 18. The distribution of prepsychotic personality, and the course in hospital are also indicated. These results may be summarized as follows. With regard to the entire group of 193 patients, a syntonic prepsychotic personality was found in 35.1 percent, a schizoid prepsychotic personality in 49.3 percent, and a psychopathic prepsychotic personality in 12.2 percent. With regard to the psychiatric status, rapport was found to be poor in 61.3 percent of the cases. The stream of talk was underproductive in 55.0 percent of the cases. 8.9 percent of the cases were mute on admission. In 55.0 percent of the cases the mood appeared to be neutral. (It must be stated that neutral mood, as objectively ascertained, does not necessarily imply absence of subjective emotionality. It is included here, since it would appear somewhat out of keeping with the general condition presented by the patient, and consequently a noteworthy finding.) 12.6 percent of the cases were described as sad, 3.1 percent as happy and 29.3 percent as other—apathetic, alert, anxious, fearful, perplexed, suspicious, benumbed. Under the heading *content,* only hallucinations and delusions are listed, since more discriminative data on content distrubances were not, as the rule, available. It is seen that hallucinations were present in 76.3 percent of all the cases. Delusions (paranoid, ideas of influence, ideas of reference, somatic) were present in 89.0 percent of all the cases. Defects in the sensorium appear as follows. Orientation was found to be defective in 55.6 percent of the cases; recent memory, in 45.2 percent; remote memory, in 42.2 percent; retention, in 64.9 percent; recall, in 73.6 percent; information, in 86.6 percent; judgment, in 96.1 percent; and insight, in 98.7 percent. Thinking was found to be scattered in 50.5 percent of all the cases. Mannerisms were present in 35.8 percent and habit deterioration in 34.7 percent. Course in hospital was found to be one of deterioration in 57.3 percent of the cases.

While it is recognized that this formalized method of assaying the clinical characteristics of the individual patient and the group as a whole is essentially descriptive rather than dynamic or psychopath-

ological, nevertheless, so far as it goes, it offers a useful means for obtaining broad objective results for subsequent comparison in connection with the various habitus types.

As the next step in the investigation of the question of a possible relationship between type of somatic habitus and kind of clinical picture, the schizophrenic patients were divided into three groups on the basis of type of habitus (determined by measurements), with the resulting distribution: asthenic type, 75 women; intermediate type, 58 women; and pyknic type, 37 women. The percentage frequency of defects in the component parts of the admission mental status examination was then determined for the patients of each type of habitus. Age at onset, prepsychotic personality and the course of the illness were also considered.

The results of this method of analysis are striking, revealing definite differences between the three schizophrenic groups differentiated on the basis of somatic type. These differences are revealed most clearly if the percentage frequencies of defects in respect of mental status items obtained for each habitus type are compared with those obtained for the schizophrenic material as a whole. Table 18 presents the percentage frequency of defects for each item in the mental status examination for the patients of asthenic habitus, intermediate habitus, and pyknic habitus. If now, the asthenic group, the intermediate group, and the pyknic group are each compared individually with the patient group as a whole, as would be expected, the habitus groups are found to fall either above (show a higher frequency of defects) or below (show a lower frequency of defects) the percentage frequency of defects for the total group. In Figure 1 is shown graphically the *way* in which the somatic groups fall above and below the values of the whole schizophrenic group for each item of the mental status. The vertical line represents, in each case, the value for the entire patient group (listed in Column 1, Table 18) for each item on the mental status. A bar to the left indicates that, in respect of that mental status item, the habitus group under consideration is *less frequently* defective than is the group as a whole. A bar to the right (cross-hatched) indicates that, in respect of that mental status item, the habitus group under consideration is *more frequently* defective than is the group as a whole. Each bar represents the absolute difference between the numerical value for the percentage frequency of defect of the habitus group and the total group, in respect of that mental

status item. Thus the difference between the asthenic group and the total patient groups in respect of poor rapport, is + 14.7, and similarly for other items.

TABLE 18

Mental status and bodily habitus

MENTAL STATUS (AND PERSONALITY TYPE)	PERCENTAGE DEFECTS IN MENTAL STATUS IN			
	Entire patient group	Asthenics	Inter-mediates	Pyknics
Prepsychotic personality				
Syntonic	35.1	32.2	36.4	41.7
Schizoid	49.3	50.8	40.9	54.2
Psychopathic	12.2	13.6	15.9	4.2
Rapport — poor	61.3	76.0	53.4	48.6
Stream of talk — underprod.	55.0	60.0	46.6	50.0
Mood — neutral	55.0	62.2	45.6	54.1
Hallucinations — present	76.3	74.6	72.5	85.7
Delusions (all types) present	89.0	85.3	90.4	94.3
Paranoid delusions present	70.6	63.8	74.5	75.8
Sensorium (defects present)				
Orientation	55.6	65.1	50.0	54.6
Recent memory	45.2	52.1	43.2	40.8
Remote memory	42.2	46.4	40.0	46.4
Retention	64.9	75.0	66.7	64.3
Recall	73.6	92.3	68.2	88.9
Information	86.6	98.1	81.6	89.3
Judgment	96.1	97.7	97.5	96.6
Insight	98.7	100.0	97.9	100.0
Thinking — scattered	50.5	58.7	45.6	38.2
Mannerisms — present	35.8	41.9	41.4	18.9
Habit deterioration — present	34.7	43.8	34.5	19.4
Course: — deteriorated	57.3	66.7	47.4	52.8

If Figure 1 is now considered in more detail, comparing first each habitus type with the findings for the schizophrenic material as a whole, the following points stand out:

1. The schizophrenic women of asthenic habitus more frequently show a schizoid and psychopathic type of prepsychotic personality and

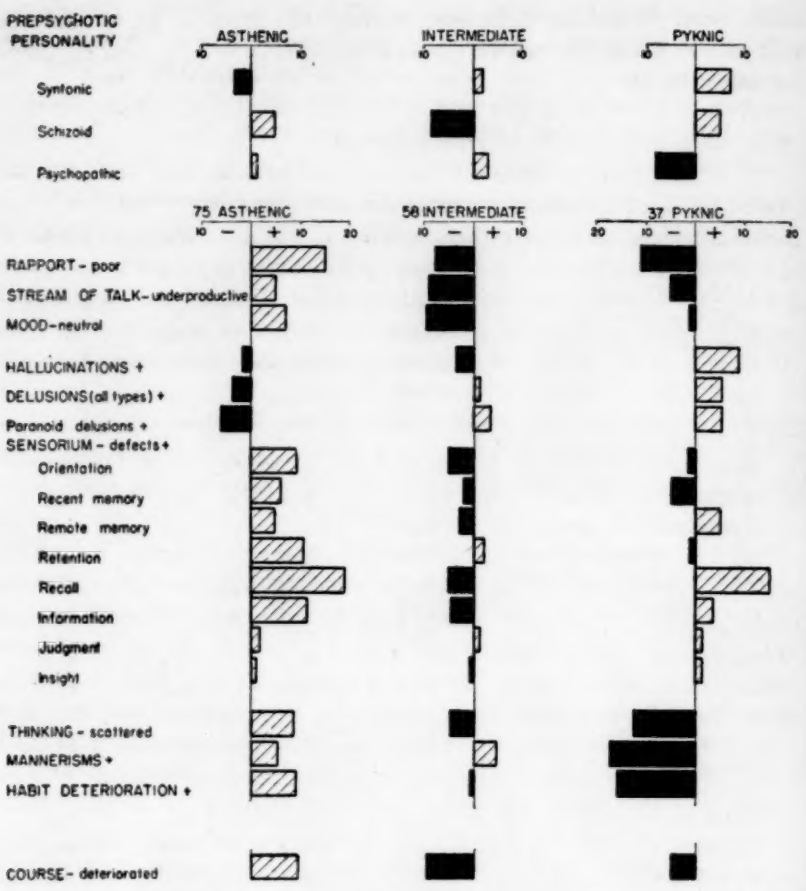

FIG. 1. VARIATIONS ABOVE (CROSS-HATCHED BARS) AND BELOW (SOLID BARS) PERCENTAGE FREQUENCY OF DEFECTS IN ADMISSION MENTAL STATUS EXAMINATION FOR SCHIZOPHRENIC GROUP AS A WHOLE (SOLID VERTICAL LINE) OF PATIENTS OF ASTHENIC, INTERMEDIATE AND PYKNIC SOMATIC HABITUS

less frequently show a syntonic type than is characteristic of the schizophrenic group as a whole. In respect of *every part* of the mental status examination, except the items relating to content (hallucinations and delusions), defects are more frequent in schizophrenic women of asthenic habitus than in the schizophrenic group as a whole. Only in respect of hallucination and delusions (all types and paranoid alone)

do the individuals of asthenic habitus fall below the frequency characteristic of the group as a whole. A deteriorated course is likewise more frequent in schizophrenic women of asthenic habitus than in the schizophrenic group as a whole. The asthenic group would seem to show more sweeping involvement than average.

2. Schizophrenic women of intermediate habitus show syntonic and psychopathic prepsychotic personalities more frequently but a schizoid personality less frequently than is true of the schizophrenic group as a whole. While they tend to show delusions, all types and paranoid, defects in retention and judgment, and the presence of mannerisms, more frequently than the schizophrenic group as a whole, in every other item of the mental status examination they fall definitely below the group as a whole in frequency of defects. The course of schizophrenic women of intermediate habitus is less frequently characterized by deterioration than is the group as a whole. The intermediate group seems to show, on the whole, less sweeping clinical involvement than average.

3. The pyknic group of schizophrenic women shows a syntonic and a schizoid type of prepsychotic personality more frequently and a psychopathic type less frequently than schizophrenic women in general. Content items (hallucinations and delusions) are distinctly more prominent in the pyknic group than in the schizophrenic group as a whole, as are sensorium defects (orientation, recent memory, and retention excepted). In all other respects, the pyknic group less frequently shows defects than the schizophrenic women as a whole. A deteriorated course is likewise less frequent.

If now the habitus groups are compared with each other, it is to be noted that:

1. The asthenic group shows a syntonic prepsychotic personality the least frequently, the pyknic group the most frequently. Interestingly enough, the pyknic group shows a schizoid personality most frequently and the intermediate group least frequently. This suggests the interpretation that, while individuals of pyknic habitus are least liable to a schizophrenic illness, when the pyknic habitus of body is coupled with schizoid personality traits, the liability to a schizophrenic reaction increases. The psychopathic personality is most prominent in the intermediate group, least prominent in the pyknic group.

2. In respect of the three items, disorientation, scattered thinking, and mannerism, it will be noted that the asthenic group is most fre-

quently defective, and the pyknic group least frequently defective. The intermediate group is less frequently defective than the asthenic in respect of orientation and thinking, but is more defective in respect of mannerisms.

3. The asthenic group and the pyknic group are almost directly complementary in the following respects: (a) whereas the asthenic group shows a greater than average frequency of poor rapport, underproductive stream of talk, and neutral mood, the pyknic group falls below average in these three respects; (b) whereas the asthenic group shows fewer than average hallucinations and delusions (all types and paranoid only), the pyknic type is more than average defective in these respects; (c) whereas scattered thinking, mannerism, and habit deterioration are more prominent in the asthenic group, they are less prominent in the pyknic group; (d) whereas a deteriorated course is more common in the asthenic group, it is less common in the pyknic group.

When age at onset of present illness is investigated, it is found that, while 60.3 percent of the asthenic group and 57.1 percent of the intermediate group became ill at 30 years of age or under, only 41.2 percent of the pyknic group became ill before the age of 31. It will be recalled that the average age at onset of illness for the group as a whole was 30.3 years. The pyknic group is clearly characterized by a later age at onset than either the asthenic or intermediate groups.

In summary, these three somatic types seem to have the following distinctive characteristics. Schizophrenic individuals of the asthenic type of somatic habitus—the type most frequently found among schizophrenic patients—least frequently show a syntonic prepsychotic personality. They become ill at a relatively early age and their clinical picture is characterized by a relatively high frequency of defects throughout the mental status examination—poor rapport, underproductive stream of talk, neutral mood, sensorium defects (including disorientation), scattered thinking, mannerisms, and habit deterioration—with, however, relatively infrequent hallucinations and delusions. This sweeping clinical picture is associated with relatively frequent deterioration in course. Schizophrenic individuals of pyknic habitus—the somatic type least frequently found among schizophrenic patients—show a relatively high frequency of both syntonic and schizoid prepsychotic personality, suggesting, as already mentioned, that a coupling of pyknic habitus of body with schizoid personality traits may increase the liability to a schizophrenic reaction. Once ill, the

clinical picture in individuals of pyknic habitus is almost directly complementary to that found in the asthenic group. Hallucinations and delusions (all types, and paranoid) are prominent, while rapport, stream of talk, thinking, and habit organization are less frequently disturbed and mannerisms are relatively infrequent. Sensorium defects which are present may be secondary to the hallucinations and delusions. While more than half of these patients deteriorate, deterioration is relatively infrequent as compared with the schizophrenic group a as whole and with the asthenic sub-group. Schizophrenic individuals of intermediate habitus—the second most frequent type found among schizophrenic patients—least frequently show a schizoid prepsychotic personality, least frequently show defects throughout the mental status, and least frequently deteriorate. The intermediate group is the only one in which less than half of the patients deteriorate. Patients of this somatic type show a rather high frequency of mannerisms.

All of these differences in percentage frequency of defects in mental status items between the groups were tested for statistical significance. Since the number of individuals in each group is relatively small, the probable errors are large, and only in the instances given below are positive tests for significance obtained. The differences shown in Figure 1 must therefore be regarded as suggestive rather than equivocally established. Significant differences were found as follows:

1. Between the asthenic and intermediate groups: in rapport, mood, presence of the defects, disorientation, scattered thinking, and mannerisms, and course.

2. Between the asthenic and pyknic groups: in rapport, mannerisms, scattered thinking, and habit deterioration.

3. Between the intermediate and pyknic groups: in mannerisms.

The implications to be drawn from these significant differences alone are in accord with the general trend shown in Fig. 1.

If the five European papers which bear on this question of somatic habitus and psychiatric status are considered, not dissimilar findings are reported. Mauz (1930), working in Kretschmer's clinic, studied 1050 cases of schizophrenia, with particular emphasis on prognostic factors, and obtained results compatible with those just reported. His findings, in relation to constitutional factors, may be summarized briefly as follows: The pyknic habitus influences against a schizophrenic "catastrophy" and favors remissions. He suggests that the

pyknic habitus may be favorable because of greater general resistance in a general medical sense to exogenous onslaught (infections, toxins). The asthenic habitus, on the other hand, acts in an unfavorable direction. Kisselew (1931) studied forty-six schizophrenic patients who were found to be distributed among the three habitus types as follows: asthenic, 14; intermediate ("muscular"), 8; and pyknic, 8. From this distribution he extracts the six cases of paranoid schizophrenia which were found to comprise two asthenics, two intermediates ("muscular"), one "middle" type, and one unclassified type. From his material, therefore, it is impossible to draw any conclusion about a characteristic somatic type in paranoid schizophrenia. Kisselew then considers the remaining six patients of "muscular" type (4 males and 2 females) and finds that they are characterized by (a) psychomotor excitement, disorientation, ill-nature, aggressiveness, anxiety feelings, and visual hallucinations, and (b) by a tendency to convulsive attacks. While these are rather general terms, they represent a certain amount of activity of the personality which may correspond to the general preservation of the mental status in the intermediate type of this study. The frequency of convulsive attacks in Kisselew's cases may be not unrelated to the prominance of mannerisms in the present material. Kisselew next considers the twelve patients of asthenic type (6 males and 6 females) whom he describes as "schizophrenia simplex", with apathy as the outstanding characteristic, and with hebephrenic components. This description, while indefinite, likewise seems in accord with the more detailed findings in this study. Finally, he considers the eight patients of pyknic habitus (3 males and 5 females), finding in them cycloid characteristics—mood swings and periodic remissions—with contactability a pronounced feature. In the pyknic group of this series, likewise, rapport was better preserved than in the other types, and scattered thinking was at a minimum. Kisselew concludes that (p. 56): " . . . jedem Körperbautypus eine eigene Symptomatologie, ein eigener Psychoseverlauf entspricht."

Plattner-Heberlein (1932) studied twenty schizophrenic men, ten of asthenic and ten of pyknic habitus, all of whom had been hospitalized eight or more years. He reports the prominance of schizoid personality in the asthenic type and that 70.0 percent of this type became ill before the age of 30, in contrast to the pyknic type in whom a syntonic personality was found and only 40.0 percent of whom became ill before the age of 30, findings well in accord with

the present study. With regard to psychiatric status, he likewise finds differences between the two types, stating (p. 313):

. . . die Psychose bei unsern Asthenikern und Pyknikern charakterische Unterschiede aufweist. Bei den Asthenikern beginnt die Krankheit in den meisten Fällen akut in jungen Jahren und führt rasch (in 1-3 Jahren) zu einem katastrophalen Zerfall mit katatonem Endausgang. Bei den Pyknikern zeigt die Krankheit meist einen späten Beginn mit relativ mildem, protrahiertem Verlauf und chronisch paranoidem Zustandsbild. Die relativ selten Paranoide der Astheniker zeigen eine starke Neigung zu destruktivem Zerfall mit Übergang in Katatonie.

He sums up the clinical characteristics of each habitus type in the following terms: The asthenic type, at onset, tends to show hypochondriacal ideas and soon develops dissociation, negativism, indifference, distortion, and general shutting-in of the personality. The pyknic type, in contrast, at onset, tends to show self-absorption and hallucinations, with content centered on the environment and affective relations to the environment relatively preserved. Again, these findings are in accord with differences found between the two types in this study.

Next, the paper of Vanelli (1932) may be mentioned. His study is based on 312 cases comprising 144 patients described as paranoid, 94 cases described as hebephrenic, 63 catatonic cases, and 14 paraphrenic cases. From the point of view of somatic habitus, he divided each of the psychiatric categories into broad type and long type, the former corresponding roughly to the term pyknic and the latter to the term asthenic. His results lead him to the following conclusion (p. 12):

"L'autore esamina 315 schizofrenici stabilendone la costituzione somatica con i metodi di Viola e di Viola-Fici e riscontra una notevole preponderanze della brachitipia nelle forme paranoide e parafreniche, mentra trava prevalenza della longitipia negli ebefrenici e nei catatonici."

Finally, Langfeldt's investigation (1937) may be considered. Studying 100 schizophrenic patients (46 males and 54 females), particularly from the viewpoint of prognosis, he found that (p. 40):

" . . . leptosome build occurs frequently in catastrophic and chronically progressing insanity, whereas the pyknic type is rare in these cases, but relatively frequent in remitting and cured cases of schizophrenia." He continues (p. 45): " . . . the leptosome type of body and the schizophynic temperament appear to be unfavourable factors, particularly when in combination. Cyclothymic temperament occurs comparatively frequently also in catastrophic and chronically progressing courses, whereas the pyknic habitus is rarely met with in such cases."

Langfeldt lists the pyknic habitus and cyclothymic temperament together with an acute onset and the presence of exogenic causes, as the most favorable prognostic features.

The results of this present study, then, and the very limited data available in the literature, strongly suggest that the somatic habitus of the individual's constitution (total personality) is indeed more than an incidental factor, not only in determining his susceptibility to a schizophrenic reaction, but in influencing the nature and course of the illness once it has taken hold. As an approach to the problem from the point of view of the individual as a unified, integrated personality, in contrast to a limited study of part systems, this should prove a stimulating avenue for further clinical observation and research.

SUMMARY AND CONCLUSIONS

A. Positive Findings

1. In respect of absolute measurements, the schizophrenic patients are significantly smaller than the control group in sitting height, stature, sternum length, xiphoid-symphysis length, right and left wrist width, body weight and right and left hand grip. In umbilical girth and in the values for chest girth, stature, and the habitus index, the schizophrenic patients show higher values than the control group. When the schizophrenic group is corrected for age, the differences in values for umbilical girth, chest girth/stature, and habitus index are the only ones to lose statistical significance.

2. In respect of the absolute measurements, the schizophrenic group consistently shows a greater range of variation than the control group. This is particularly noted in pulse rate.

3. In respect of absolute measurements, the schizophrenic group, in comparison with the values recorded in the literature for other series of individuals, is consistently smaller.

4. Whether the schizophrenic material is divided into types of somatic habitus on the basis of impression or on the basis of differentiating anthropometric measurements, the asthenic type is most frequent, the intermediate type next, and the pyknic type least frequent. In the control group, the intermediate type stands first, with the asthenic type second, and the pyknic third. When these distributions are compared with distributions for schizophrenic and non-schizophrenic individuals in the literature, it is demonstrated that the asthenic type

has been found more frequently and the pyknic type less frequently in schizophrenic patients than in non-schizophrenic individuals.

5. When the psychiatric status of schizophrenic patients of each habitus type, as determined by findings on admission mental status examination is determined, clear-cut differences are demonstrated. (a) Patients of asthenic habitus are found least frequently to have a syntonic personality type; defects *throughout* the mental status are relatively more prominent than in the other types, excepting in respect of hallucinations and delusions which are relatively less prominent. The three defects, disorientation, scattered thinking, and mannerisms, are more prominent in patients of asthenic habitus. A deteriorated course is relatively more frequent than in the other types. (b) Patients of pyknic habitus show both a syntonic and a schizoid personality more frequently than the other two types. Findings on admission mental status examination tend to complement those found in the asthenic type: hallucinations and delusions (all types, and paranoid) are prominent, rapport and speech are relatively preserved as are thinking, habits of dress, and sphincter control, and motor control. Deterioration, while occurring in over half of the cases is less frequent than in the asthenic group. (c) Patients of intermediate habitus show the schizoid personality least frequently. The admission mental status examination is relatively less defective than in the other two types, except for the rather prominent presence of mannerisms. Deterioration is relatively less frequent, occurring in less than half of the cases.

6. Onset of present illness is relatively more frequent before the age of 30 in patients of asthenic and intermediate habitus; after the age of 30, in patients of pyknic habitus.

7. A methodological procedure for determining habitus type on the basis of significantly distinctive objective anthropometric measurements is demonstrated.

B. Conclusions

Results of an investigation of the somatological status of 193 schizophrenic women, both in relation to the somatological status of non-schizophrenic individuals and in relation to their own psychiatric status lead to the following general conclusions:

1. Schizophrenic patients, in respect of their somatic dimensions, are small people as human beings go.

2. The psychomotor response of schizophrenic patients is inadequate as compared with normal individuals, as measured by their ability to register hand grip.

3. The pulse rate is more variable in schizophrenic patients than in normal individuals, suggesting a greater autonomic instability.

4. The asthenic type of somatic habitus is more common and the pyknic type less common in schizophrenic patients than in non-schizophrenic individuals. This weighting of the distribution persists whether an impressionistic method of typing is used or whether typing is determined by objective standards based on anthropometric measurements, and whether the factor of age is considered or not.

5. While the pyknic type of habitus tends to appear somewhat more frequently with increase in mean age in schizophrenic patients, this is believed due not only to an age factor, but to the fact that patients of pyknic habitus are older at age of onset of present illness than patients of other somatic types.

6. A certain association is found between somatic habitus and personality type, in that the syntonic personality is least frequently found in the asthenic habitus and most frequently found in the pyknic habitus. The schizoid personality is least frequently found in the intermediate habitus and most frequently found in the pyknic habitus. It is suggested that, whereas individuals of pyknic habitus seem least frequently to develop a schizophrenic reaction, their exposure to risk in the presence of schizoid personality traits may increase.

7. Somatic habitus may operate as a dynamic factor in the genesis and clinical development of the schizophrenic reaction. The asthenic habitus is associated with more ominous mental status defects, and with more frequent deterioration in course. The pyknic habitus is less prominently associated with a sweepingly defective mental status, and with deterioration in course, but is associated with a high frequency of hallucinations and delusions. The intermediate type shows the best preservation of the mental status, and the least tendency toward deterioration. It is particularly characterized by the presence of mannerisms.

APPENDIX

PROCEDURE FOR DETERMINING AN OBJECTIVE ANTHROPOMETRIC STANDARD FOR USE IN DETERMINING HABITUS TYPE

Pearl (1940, p. 344) states that " . . . an obligate prerequisite to any attempt at a rational biological analysis of human somatology is

to have first an accurate quantitative description of the phenomena it is proposed to analyze, namely human shapes and sizes. This description can only be furnished by sound, critical, intelligent and honest anthropometry." The following pages are devoted to the description of a procedure for setting up an objective standard based on somatic measurements and index values by means of which human beings can be separated into the four generally accepted bodily types—asthenic, intermediate, pyknic, and dysplastic. The final standard consists of a table of measurements which is, essentially, a translation into quantitative terms of the differences in dimensions utilized roughly in sorting out bodily types by the method of subjective impression. In an extreme asthenic or pyknic build, classification by impression is accurate and a more refined description is of no practical interest. In less extreme types, classification becomes more difficult and some criteria of division between types must be adopted. The determination of these division points becomes the crucial consideration in developing an objective anthropometric standard. The essential questions would seem to be: Above or below what anthropometric values does the characteristic range in respect of stature (chest depth, umbilical girth, etc.) lie for the asthenic, the intermediate, the pyknic? To what extent do the characteristic ranges overlap, to what extent are they distinct?

As the first step towards an answer to these questions the values for each somatic variable and index were grouped into class units corresponding in each case to tenths (deciles) of the total range for the variable concerned. The ten resulting frequency classes for each variable were then assembled into three *sections*, a lower, middle, and upper (Table A). The dividing points were chosen arbitrarily at the decile unit (usually the 4th and 6th, in three cases the 3rd and 7th, and in one case each the 3rd and 5th and the 5th and 7th) which seemed to insure the most even distribution of the cases into the three sections.

The total material of 193 schizophrenic women was next separated into the three habitus types as determined by impression. Frequency distributions were then set up, showing the number of individuals of each of the three habitus types whose measurements for each somatic variable fell in the lower, the middle, or the upper section of the distribution for that variable. Thus for stature, of the 69 asthenic women, forty, or 57.9 percent, had a stature of 156.59 cms. or under; twenty-five, or 36.2 percent, had a stature of between 156.6 cms. and

162.19 cms.; and only four, or 5.9 percent, had a stature of 162.2 cms. or over. The absolute frequency and the percentage frequency distributions of the individuals of each type of habitus in respect of the triple divisions of the scale for all of the somatic variables are presented in Table B.

TABLE A

Division of range of somatic variables into lower, middle, and upper sections

SOMATIC VARIABLE	LOWER SECTION	MIDDLE SECTION	UPPER SECTION
Head girth.....	49.2 — 52.9	53.0 — 54.8	54.9 — 58.7
Head breadth.....	13.3 — 14.37	14.38 — 14.91	14.92 — 16.0
Head length.....	16.2 — 17.55	17.56 — 18.23	18.24 — 19.60
Sitting height.....	72.9 — 80.77	80.78 — 84.71	84.72 — 92.6
Stature	145.4 — 156.5	156.6 — 162.1	162.2 — 173.4
Sternum length.....	10.5 — 14.73	14.74 — 16.85	16.86 — 21.1
Xiphoid-symphysis...	19.2 — 32.51	32.52 — 39.17	39.18 — 52.5
Biacromial	24.1 — 31.74	31.75 — 34.80	34.81 — 39.4
Bicristal	24.5 — 28.37	28.38 — 30.31	30.32 — 34.2
Chest depth.....	12.7 — 16.61	16.62 — 18.57	18.58 — 22.5
Wrist width—right..	4.3 — 4.89	4.90 — 5.19	5.2 — 5.8
Chest girth.....	58.9 — 73.23	73.24 — 87.57	87.58 — 106.7
Umbilical girth.....	55.6 — 79.65	79.66 — 95.69	95.70 — 135.8
Weight	76.0 — 116.1	116.2 — 169.7	169.8 — 210.0
Chest girth/Stature..	39.1 — 46.56	46.57 — 56.52	56.53 — 64.0
Weight/Stature	49.0 — 73.2	73.3 — 105.6	105.7 — 130.0
Habitus index.....	75.7 — 99.81	99.82 — 111.87	111.88 — 136.0

In looking over Table B, it at once becomes evident that striking differences in the percentage frequencey of distribution of individuals of the three types of habitus exist. It is to be emphasized that such differences are hardly unexpected, since it was on the broad differences between these individuals that they were originally separated into four categories by impression. The important point now is, not that differences are demonstrated, but that these differences are expressed in an orderly fashion in quantitative terms capable of further analysis.

The next step is to test these differences in percentage frequencies between one type and another for significance, to determine which are

TABLE B

Absolute and percentage frequency distributions of individuals of asthenic, intermediate, and pyknic habitus in respect of the different somatic variables demarcated according to range into three sections

SOMATIC VARIABLE	ASTHENIC		INTERMEDIATE		PYKNIC	
	No.	*Percent*	*No.*	*Percent*	*No.*	*Percent*
Head girth (cms.)						
52.9 and under	32	46.3	8	18.2	7	21.9
53.0 — 54.89	34	49.2	24	54.5	10	31.2
54.9 and over	2	4.5	12	27.3	15	46.9
Head breadth (cms.)						
14.37 and under	32	46.3	16	36.3	10	31.2
14.38 — 14.91	30	43.4	16	36.3	11	34.4
14.92 and over	7	10.3	2	27.4	11	34.4
Head length (cms.)						
17.55 and under	26	37.6	5	11.4	3	9.4
17.56 — 18.23	28	40.5	19	43.2	16	50.0
18.24 and over	15	21.9	20	45.4	13	40.6
Sitting height (cms.)						
80.77 and under	28	40.5	10	22.6	12	37.5
80.78 — 84.71	37	53.6	22	50.0	26	50.0
84.72 and over	4	5.9	12	27.4	4	12.5
Stature (cms.)						
156.59 and under	40	57.9	9	20.5	20	62.5
156.6 — 162.19	25	36.2	19	43.2	9	28.1
162.2 and over	4	5.9	16	36.3	3	9.4
Sternum length (cms.)						
14.73 and under	26	37.6	8	15.8	6	18.7
14.74 — 16.85	38	55.0	26	63.7	20	62.5
16.86 and over	5	7.4	9	20.5	6	18.7
Xiphoid-symphysis (cms.)						
32.51 and under	49	71.0	26	63.7	12	37.5
32.52 — 39.17	20	29.0	16	36.3	14	43.8
39.18 and over	0	0.0	0	0.0	6	18.7
Biacromial (cms.)						
31.74 and under	29	42.0	11	25.0	11	34.4
31.75 — 34.80	36	52.1	22	50.0	15	46.9
34.81 and over	4	5.9	11	25.0	6	18.7
Bicristal (cms.)						
28.37 and under	51	73.9	15	34.1	8	25.1
28.38 — 30.31	17	24.6	24	54.5	14	43.7
30.32 and over	1	1.5	4	11.4	10	31.2

TABLE B (*Continued*)

SOMATIC VARIABLE	ASTHENIC		INTERMEDIATE		PYKNIC	
	No.	*Percent*	*No.*	*Percent*	*No.*	*Percent*
Chest depth (cms.)						
16.61 and under	58	84.0	20	46.5	5	15.7
16.62 — 18.57	11	16.0	17	39.5	14	43.7
18.58 and over	0	0.0	6	14.0	13	40.6
Wrist width — right (cms.)						
4.89 and under	36	52.1	10	23.2	7	21.9
4.9 — 5.19	23	33.3	20	46.5	13	40.6
5.2 and over	8	14.6	13	30.3	12	37.5
Chest girth (cms.)						
73.23 and under	64	92.7	23	52.2	3	9.7
73.24 — 87.57	5	7.3	21	47.8	24	77.4
87.58 and over	0	0.0	0	0.0	4	12.9
Umbilical girth (cms.)						
79.65 and under	66	97.1	18	41.9	0	0.0
79.66 — 95.69	2	2.9	25	58.1	12	37.5
95.70 and over	0	0.0	0	0.0	20	62.5
Weight (lbs.)						
116.19 and under	68	100.0	15	34.1	2	6.3
116.2 — 169.78	0	0.0	29	65.9	21	65.6
169.8 and over	0	0.0	0	0.0	9	28.1
Chest girth/Stature						
46.56 and under	61	88.4	27	62.8	4	12.5
46.57 — 56.52	8	11.6	16	37.2	22	68.8
56.53 and over	0	0.0	0	0.0	6	18.7
Weight/Stature						
73.29 and under	69	100.0	13	29.6	0	0.0
73.3 — 105.69	0	0.0	31	70.4	17	53.1
105.7 and over	0	0.0	0	0.0	15	46.9
Habitus index						
99.81 and under	67	98.5	29	67.2	0	0.0
99.82 — 111.87	1	1.5	14	32.8	12	38.7
111.87 and over	0	0.0	0	0.0	19	61.3

fundamental and which are essentially unimportant. To do this, dichotomies rather than triple divisions are necessary for technical reasons, and Table C, based on Table B, was set up. In making the transition from a triple to a dichotomus division of the material, the procedure of choice, in a rigidly scientific sense, would be to contrast

only the lower and upper sections, omitting the cases in the middle, transition, section entirely. However, two objections to this method of procedure seem to warrant a more flexible approach. In the first place, for statistical purposes it seemed undesirable to reduce the number of cases in the final dichotomies by entirely discarding those which fall in the middle section. In the second place, as emphasized in the text, variations in human habitus are recognized as distributed in a continuous manner, and it seemed unwise to introduce a hiatus in the continuity of a distribution by omitting cases falling in the middle range between the upper limit of the lower section and the lower limit of the upper section. It was determined, therefore, to combine two contiguous sections and compare them with the remaining section (lowest and middle against upper; lowest against middle and upper). In Table C, the scale for stature, for example, is divided into two instead of three sections by combining, first, the middle and upper sections (156.6 cms. and over) in contrast to the lowest section (156.5 cms. and under), and second, the lowest and middle section (162.19 and under) in contrast to the upper section (162.2 cms. and over). The frequency distributions in the first case then become: forty women of asthenic habitus, or 57.9 percent, fall in the lowest section while twenty-nine, or 42.1 percent, fall in the remaining part of the range. The frequency distributions in the second case become: sixty-five women of asthenic habitus, or 94.1 percent, fall in the lower part of the range while four, or 5.9 percent, fall in the upper section.

The differences between these percentage frequencies among the three types of habitus were then tested for statistical significance in the usual manner, and the results for each somatic variable indicated qualitatively in the extreme right hand column of Table C where the heading A-I indicates the comparison between asthenic and intermediate; A-P, between asthenic and pyknic; and I-P, between intermediate and pyknic. The sign $<$ means a difference "significantly less than", the sign $>$ a difference "significantly greater than", and a dash (—) "no significant difference." By reading down this column it is possible to see at a glance where significant differences are found and what the nature of these differences is. Thus, for stature, asthenics are more frequently shorter (156.59 cms. and under) than intermediates but do not differ significantly from pyknics. Intermediates, however, are significantly taller than pyknics (more frequently 156.6 cms. or over). Similarly, for head girth, asthenics are significantly smaller than intermediates

TABLE C

Absolute and percentage frequency distributions of individuals of asthenic, intermediate and pyknic habitus in respect of the different somatic variables demarcated according to range into two sections

Significant differences in percentage frequencies between the types are indicated in the right hand column.

SOMATIC VARIABLE	ASTHENIC		INTERMEDIATE		PYKNIC		SIGNIFICANT DIFFERENCES		
	No.	*Percent*	*No.*	*Percent*	*No.*	*Percent*	A-I	A-P	I-P
Head girth (cms.)									
52.9 and under.....	32	46.3±4.0	8	18.2±3.9	17	21.9± 4.9	<	<	—
53.0 and over.....	37	53.7	36	81.8	25	78.1			
54.89 and under.....	66	95.5±5.3	32	72.6±4.5	17	53.1± 5.2	<	<	—
54.9 and over.....	3	4.5	12	27.4	15	46.9			
Head breadth (cms.)									
14.91 and under.....	62	89.7±2.5	32	72.6±4.5	21	65.6± 5.6	<	<	—
14.92 and over.....	7	10.3	12	27.4	11	34.4			
Head length (cms.)									
17.55 and under.....	26	37.6±4.4	5	11.4±3.2	3	9.4±10.9	<	—	—
17.56 and over.....	43	62.4	39	88.6	29	90.6			
Sitting height (cms.)									
80.77 and under.....	28	40.5±3.9	10	22.6±4.2	12	37.5± 5.8	<	—	—
80.78 and over.....	41	59.5	34	77.4	20	62.5			
Stature (cms.)									
156.59 and under....	40	57.9±4.0	9	20.5±4.1	20	62.5± 5.8	<	—	>
156.6 and over.....	29	42.1	35	79.5	12	37.5			
162.19 and under....	65	94.1±6.0	28	63.7±4.9	29	90.6±10.9	<	—	—
162.2 and over.....	4	5.9	16	36.3	3	9.4			
Sternum length (cms.)									
14.73 and under.....	26	37.6±3.9	8	15.8±3.7	6	18.7± 4.6	<	<	—
14.74 and over.....	43	62.4	35	84.2	26	81.3			
Xiphoid-symphysis (cms.)									
32.51 and under.....	49	71.0±3.7	26	63.7±5.0	12	37.5± 5.8	—	<	<
32.52 and over.....	20	29.0	16	36.3	20	62.5			
Biacromial (cms.)									
31.74 and under.....	29	42.0±4.0	11	25.0±4.4	11	34.4± 5.7	<	—	—
31.75 and over.....	40	58.0	33	75.0	21	65.6			

TABLE C *(Continued)*

SOMATIC VARIABLE	ASTHENIC		INTERMEDIATE		PYKNIC		SIGNIFICANT DIFFERENCES		
	No.	*Percent*	*No.*	*Percent*	*No.*	*Percent*	A-I	A-P	I-P
Bicristal (cms.)									
28.37 and under.....	51	73.9±3.6	15	34.1±4.8	8	25.1± 5.2	<	<	—
28.38 and over.....	18	26.1	28	65.9	24	74.9			
30.31 and under.....	68	98.5±3.1	39	88.6±3.2	22	68.8± 5.5	—	<	<
30.32 and over.....	1	1.5	4	11.4	10	31.2			
Chest depth (cms.)									
16.61 and under.....	58	84.0±2.9	20	46.5±5.1	5	15.7± 4.3	<	<	<
16.62 and over.....	11	16.0	23	53.5	27	84.3			
Wrist width—right (cms.)									
4.89 and under.....	36	52.1±3.2	10	23.2±3.2	7	21.9± 4.89	<	<	—
4.9 and over.....	31	47.9	33	76.8	25	78.1			
Chest girth (cms.)									
73.23 and under.....	64	92.7±6.7	23	52.2±5.1	3	9.7±11.3	<	<	<
73.24 and over.....	5	7.3	21	47.8	28	91.3			
Umbilical girth (cms.)									
79.65 and under.....	66	97.1±4.3	18	41.9±5.1	0	0.0	<	<	<
79.66 and over.....	2	2.9	25	58.1	32	100.0			
Weight (lbs.)									
116.19 and under....	68	100.0	15	34.1±4.8	2	6.3± 9.2	<	<	—
116.2 and over.....	0		29	65.9	28	93.7			
Chest girth/stature									
46.56 and under.....	61	88.4±2.5	27	62.8±4.9	4	12.5± 3.9	<	<	<
46.57 and over.....	8	11.6	16	37.2	28	87.5			
Weight/stature									
73.29 and under.....	69	100.0	13	29.6±4.6	0	0.0	<	<	<
73.3 and over.....	0		31	70.4	32	100.0			
Habitus index									
99.81 and under.....	67	98.5±2.2	29	67.2±5.1	0	0	<	<	<
99.82 and over.....	1	1.5	14	32.8	43	100.0			

and pyknics, while intermediates and pyknics do not differ significantly from each other.

These relations of each of the types to each other, in respect of the various somatic variables, are expressed verbally in Table D. This table shows qualitatively in what respects each type of habitus resembles each other type, differs from each other type, and where overlapping occurs. (Of all of the somatic variables listed in Table 1 (first part

TABLE D

Comparison of interrelationships of the asthenic, intermediate, and pyknic habitus types in respect of absolute measurements and significant indices

ASTHENICS AND INTERMEDIATES (*Differ in 15 characteristics*)

I. Similar in:
   Xiphoid-symphysis length
II. Asthenics smaller in:
   Head girth, breadth and length
   Sitting height, stature, and sternum length
   Biacromial width, bicristal width and wrist width
   Chest girth and umbilical girth
   Weight
   Chest girth/stature and weight/stature
   Chest depth
III. Asthenics larger in: 0

ASTHENICS AND PYKNICS (*Differ in 12 characteristics*)

I. Similar in:
   Head length, sitting height, stature and biacromial width
II. Asthenics smaller in:
   Head girth and breadth
   Sternum length and xiphoid-symphysis length
   Bicristal width and wrist width
   Chest depth
   Weight
   Chest girth/stature and weight/stature
   Chest girth and umbilical girth
III. Asthenics larger in: 0

INTERMEDIATES AND PYKNICS (*Differ in 8 characteristics*)

I. Similar in:
   Head girth, breadth and length
   Sitting height and sternum length
   Biacromial width and wrist width
   Weight
II. Intermediates smaller in:
   Xiphoid-symphysis length
   Bicristal width
   Chest depth
   Chest girth and umbilical girth
   Sitting height/stature and chest girth/stature
III. Intermediates larger in:
   Stature

TABLE E

Comparison of interrelationships of the asthenic, intermediate and pyknic habitus types in respect of absolute measurements and significant indices

(From Burchard, 1937, p. 37.)

ASTHENICS AND INTERMEDIATES		*(Differ in 5 characteristics)*
I. Similar in:		
Chest depth	W-H index	
Stature	Length of leg	
Sitting height		
II. Asthenics smaller in:		
Biacromial width	Chest width	
Bicristal width	Trunk length	
Weight		
III. Asthenics larger in: o		
ASTHENICS AND PYKNICS		*(Differ in 9 characteristics)*
I. Similar in:		
Trunk height		
II. Asthenics smaller in:		
Weight	Chest width	
Biacromial width		
Bicristal width		
Chest depth		
III. Asthenics larger in:		
Stature	Leg length	
Sitting height	W-H index	
INTERMEDIATES AND PYKNICS		*(Differ in 5 characteristics)*
I. Similar in:		
Weight	Chest width	
Sitting height	W-H index	
Biacromial width		
II. Intermediates smaller in:		
Chest depth		
III. Intermediates larger in:		
Bicristal width	Leg length	
Stature	Trunk length	

of this paper), only in the following were no significant differences found, and they are consequently omitted from the table: pulse rate, sitting height/stature, biacromial width/stature, biacromial width/bicristal width, sternum length/xiphoid-symphysis. The data on the dysplastic group are omitted, since the results scattered so widely across the other three groups that no significant pattern could be formulated.)

In comparison with Table D, the findings of Burchard (1936, p. 37) on 407 white male patients comprising 13 psychiatric categories are of interest. Pursuing essentially the same line of reasoning to this point, his results are in some respects similar, in some respects different, from those obtained in the present sample. His results are presented in tabular form (Table E), comparable to the results of this study shown in Table D. It will be noted that only six of the same somatic variables are used in both studies, namely: stature, sitting height, biacromial width, bicristal width, chest depth and weight.

If the results of the two studies in respect of these six somatic variables are compared, it will be noted that both studies *agree* in the following respects:

1. Weight is a significant somatic variable for differentiating the asthenic type from the intermediate and pyknic types of somatic habitus.

2. Bicristal width is a significant somatic variable in differentiating the asthenic type from the intermediate and pyknic types.

3. Biacromial width is a significant somatic variable in differentiating the asthenic from the intermediate type.

4. Chest depth is a significant somatic variable in differentiating the asthenic type from the pyknic type, and the intermediate type from the pyknic type.

5. Stature is a significant somatic variable in differentiating the intermediate type from the pyknic type.

6. Weight and sitting height do not vary significantly between the intermediate type and the pyknic type.

The two studies fail to agree in the following respects:

1. The asthenic type is smaller than the intermediate type in chest depth, stature, and sitting height (this study); similar in these respects (Burchard).

2. The asthenic type is similar to the pyknic type in sitting height and stature (this study); larger in these respects (Burchard).

3. The asthenic type is similar to the pyknic type in biacromial width (this study); small in this respect (Burchard).

4. The intermediate type is similar to the pyknic type in biacromial width (this study); larger in this respect (Burchard).

While Burchard's results are not strictly comparable since the measurements were obtained on males rather than females, the points in which the two studies agree and disagree are of great interest. Wherever the results disagree, and one habitus type is smaller in a certain respect than another in one study, but not in the other, it will be noted that in the second study the relationship is never reversed, but any differences found to exist are simply found to be insignificant statistically.

While Burchard does not carry these qualitative formulations of the behavior of the different somatic variables in each of the habitus types further, it was felt desirable in the present inquiry to translate them to quantitative terms, substituting for the verbal formulations in Table D, appropriate anthropometric values. These values were easily obtained from Table C, on which Table D is based, and are presented in Table F. Table F, then, represents an objective set of anthropometric criteria for determining somatic habitus. It shows the range of values characteristic of each type of habitus, points of demarcation distinguishing one type from another and areas of overlapping between the types. As would be expected when the continuity of variation in habitus is emphasized, overlapping occurs only between asthenic and intermediate and intermediate and pyknic, never between asthenic and pyknic alone (in respect of four variables, head breadth and length, sitting height, and biacromial width, the pyknic type overlaps both intermediate and asthenic). Vertical, horizontal, circumferential, and ponderal measurements are all considered, each is allowed to act independently but is only applied in determining habitus together with all of the others. Since this particular table is based on psychotic individuals who have been shown to run, as a group, below average in size for women in general so far as data for comparison are available, and since the number of cases on which the table is based is relatively small, the exact anthropometric ranges constituting it are not advanced as any ultimate standard for determining somatic habitus universally. Nevertheless, the approach seems reasonable and a similar table worked out on an unselected and adequately large sample of individuals would reduce the subjective factor in constitutional studies to a minimum and have considerable value in placing the technique of typing on a scientifically sound basis. Actually, the results obtained in this study compare

very well with the mean values recorded in the literature for female asthenic, intermediate, and pyknic habitus, as compiled in Table G from the papers of Olivier (1922), Kretschmer (1925), and Ciocco (1936).

TABLE F

Summary of numerical values for somatic variables for use as point of demarcation in distinguishing one type of somatic habitus from another

SOMATIC VARIABLES	ASTHENIC	INTERMEDIATE	PYKNIC
Head girth (cms.)	54.89 and less	53.0 and over	53.0 and over
Head breadth (cms.)	14.91 and less	No limits	No limits
Head length (cms.)	18.23 and less	17.56 and over	No limits
Sitting height (cms.)	84.71 and less	80.78 and over	No limits
Stature (cms.)	162.1 and less	156.6 and over	162.1 and less
Sternum length (cms.)	16.85 and less	14.74 and over	14.74 and over
Xiphoid-symphysis (cms.)	39.17 and less	39.17 and less	32.52 and over
Biacromial width (cms.)	34.80 and less	31.75 and over	No limits
Bicristal width (cms.)	28.37 and less	30.31 and less	28.38 and over
Chest depth (cms.)	16.61 and less	18.57 and less	16.62 and over
Wrist width—right (cms.)	5.1 and less	4.9 and over	4.9 and over
Chest girth (cms.)	73.23 and less	87.58 and less	73.24 and over
Umbilical girth (cms.)	79.65 and less	95.6 and less	79.66 and over
Weight (lbs.)	116.1 and less	116.2 — 169.8	116.2 and over
Chest girth/Stature	46.56 and less	56.52 and less	46.57 and over
Weight/Stature	73.2 and less	105.6 and less	73.3 and over
Habitus index	99.81 and less	111.87 and less	99.82 and over

The procedure followed in using this table of criteria for determining the habitus of a given individual is as follows: the values for each somatic variable recorded on the anthropometric sheet on each patient were compared with the fourteen somatic variables and three indices listed in Table F. A notation was made on the patient's sheet to the left of each of the seventeen somatic variables indicating whether this value fell within the range listed in the Table for asthenic (A), intermediate (I), or pyknic (P). Since overlapping is common, the

TABLE G

Comparison of mean values recorded in the literature for various somatic variables in females of asthenic, intermediate, and pyknic habitus type with results obtained in this study

AUTHORITY	ASTHENIC	INTER-MEDIATE	PYKNIC	NUMBER	DIAGNOSIS
			Height		
Olivier	154.0	160.0	154.0	...	Schizophrenia
Kretschmer	153.8	163.1	156.5	92	Manic-depressive and schizophrenia
Ciocco	156.1	156.9	153.9	126	Cardiacs
Ciocco	161.5	155.6	150.0	37	Non-cardiacs
This paper	162.1 and under	156.6 and over	162.1 and under	193	Schizophrenia
			Weight		
Olivier	46.0	57.0	54.2	...	Schizophrenia
Kretschmer	32.8	61.7	56.3	92	Manic-depressive and schizophrenia
Ciocco	54.2	66.2	82.0	126	Cardiacs
Ciocco	47.0	59.5	70.0	37	Non-cardiacs
This paper	52.8 and under	52.8—77.2	52.8 and over	193	Schizophrenia
			Biacromial width		
Olivier	32.6	37.2	34.3	...	Schizophrenia
Kretschmer	34.4	37.4	34.3	...	Schizophrenia
This paper	34.8 and under	31.75 and over	No limits	...	Schizophrenia
			Abdominal girth		
Olivier	67.5	75.0	79.0	...	Schizophrenia
Kretschmer	67.7	95.8	78.7	...	Schizophrenia
This paper	79.65 and under	95.6 and under	79.66 and over	...	Schizophrenia
			Head girth		
Olivier	53.8	55.0	54.2	50	Schizophrenia
Kretschmer	53.6	54.8	54.5	50	Schizophrenia
This paper	54.89 and under	53.0 and over	53.0 and over	...	Schizophrenia
			Head breadth		
Kretschmer	15.0	15.4	15.0	50	Schizophrenia
This paper	14.9 and under	No limits	No limits	...	Schizophrenia
			Head length		
Kretschmer	17.0	17.6	17.1	50	Schizophrenia
This paper	18.23 and under	17.56 and over	No limits	...	Schizophrenia

value for a single variable might be characteristic of any two or all three types, and the completed list look something as follows:

Anthropometric

A I P	Head girth — 54.6
A I P	Head breadth — 14.6
A I P	Head length — 18.1
I P	Sitting height — 89.6
I	Stature — 173.4
I P	Biacromial width — 35.2
P	Bicristal width — 30.6
A I	Xiphoid-symphysis — 31.7
A I P	Sternum length — 16.1
I P	Wrist width — right — 5.3
A I	Chest depth — 15.3
A I	Chest girth — 69.0
A I	Umbilical girth — 73.5
I P	Weight — 129.0
A I	Chest girth/Stature — 39.9
I P	Weight/Stature — 75.0
A I	100 (Chest girth + Abdominal girth)/Stature

The amount of overlapping which occurs in any one individual in respect of not only one, but several, individual somatic variables is impressively shown in this left-hand column.

The next step in arriving at an estimation of the individual's type is as follows: the number of times out of a possible seventeen that A, and I, and P appears in the left-hand column is totaled. Then:

1. If any *one* type (A, or I, or P) appears 15, 16, or 17 times, and the other two types 14 or less times, the patient is classified as a "pure" asthenic (or intermediate or pyknic).

2. If any *two* types appear 15, 16, or 17 times, and the third type 14 or less times: (a) If *each* of the two types is found 15 times, *or* 16 times, *or* 17 times, the individual is considered as much one type as another, and is classified as dysplastic; (b) If one of the two types is found 15 times and the other 16 or 17 times, or if one is found 15 or 16 and the other 17 times, the individual, while not considered "pure", is regarded as *more like* the type which is found more frequently, and is classed as such.

3. If *none* of the three types appear 15, 16, or 17 times, the individual is classified as dysplastic, since no single type predominates. No cases were found in which all three types appear 15 or more times.

In the above example, A appears 10 times; I, 16 times; and P, 10 times. This patient, therefore, is classified as an intermediate type, the habitus type, incidentally, to which she had been assigned impressionistically. In similar fashion, the entire material of this study was reclassified. The results may be summarized briefly (Table 17): An asthenic group of 75 women is found (consisting, by impressionistic typing, of 54 asthenics, 4 intermediates, 16 dysplastics, and 1 pyknic); an intermediate group of 58 women (consisting, by impressionistic typing of 33 intermediates, 4 asthenics, 4 pyknics, and 17 dysplastics); a pyknic group of 37 women (consisting, by impressionistic typing, of 25 pyknics, 10 dysplastics, 2 intermediates, and no asthenics); and a dysplastic group of 23 women (consisting, by impressionistic typing, of 5 dysplastics, 11 asthenics, 5 intermediates, and 2 pyknics).

The significance of these results in relation to the immediate problem of the schizophrenic psychosis and somatic habitus is considered in the text of this study.

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INTRACRANIAL VARIATION IN THE WEIGHT OF THE HUMAN BRAIN (*Concluded*)

BY F. W. APPEL AND E. M. APPEL

VARIATION IN BRAIN WEIGHT BY CAUSES OF DEATH

THE total number of primary and secondary causes of death for the 2080 cases with non-lesioned brains should be 4160. But 386 causes were never assigned (or, rather, they are not given on the data sheets), hence only 3774 causes are known. These are accounted for in Table 7. The groupings are those of the International List (4th revision), with three exceptions. The miscellaneous category (183 causes) includes a variety of infectious and degenerative diseases, none of which occurs frequently enough for definitive statistical analysis. Tuberculosis has been listed by itself, since there are enough cases of this infectious disease to form a sizeable group. Finally, arteriosclerosis has been listed separately although it is included in the group of circulatory diseases.

Of the total number of assigned causes of death, 25 percent are diseases of the circulatory system. There are even more respiratory diseases (27 percent), for this category includes the terminal pneumonias and respiratory congestions which are prevalent in any autopsy population. Diseases of the nervous system account for only 11 percent of the combined causes of death — not a very large proportion, considering that the cases come from a mental hospital. Tuberculosis, the circulatory diseases, and the respiratory diseases all outrank the nervous diseases as causes of death.

The mean weight of the brain is highest for the cases of violent and accidental deaths. This group includes the suicides and the men who died through accidents while working. In other words, it includes some of the more active patients. No attempt will be made to show that these men were larger than the men in other groups, or that their mean body weight was greater. The records as to size are infrequent, and the statements about size are too general, to make a statistical study worthwhile. Occasionally a record states that a patient was "fairly well

nourished", or that he was "rather emaciated", but little use can be made of this information. It can be said, however, that many of the patients who came to violent and accidental deaths were robust, and that the group as a whole had suffered relatively little physical wasting due to disease.

TABLE 7

Variation in brain weights according to causes of death
(Non-lesioned-brain cases)

CAUSE OF DEATH	NUMBER	RANGE (grams)	MEAN (grams)	MEDIAN (grams)	STANDARD DEVIATION (grams)	COEFFICIENT OF VARIATION (percent)
Tuberculosis	533	1000–1750	1328.24± 3.54	1326.84± 4.44	121.15±2.50	9.12±0.19
Cancer	112	950–1630	1275.00± 7.56	1278.79± 9.48	118.65±5.35	9.31±0.42
Diseases of the nervous system	430	870–1640	1285.35± 4.37	1277.27± 5.48	134.38±3.09	10.46±0.24
Arterio-sclerosis	358	971–1720	1273.18± 4.17	1270.09± 5.23	116.98±2.95	9.19±0.23
Diseases of the circulatory system, including arterio-sclerosis	955	971–1700	1295.03± 2.69	1289.06± 3.37	123.00±1.90	9.50±0.15
Diseases of the respiratory system	1023	870–1750	1300.34± 2.79	1294.37± 3.49	132.15±1.97	10.17±0.15
Diseases of the digestive system	284	1000–1750	1307.39± 4.97	1316.49± 6.23	124.16±3.51	9.50±0.27
Diseases of the urogenital system	200	934–1720	1315.00± 6.58	1313.85± 8.25	137.99±4.65	10.50±0.36
Violent and accidental deaths	54	1135–1729	1374.07±13.42	1352.63±16.82	146.17±9.49	10.64±0.70
Miscellaneous	183					
Not given	386					
Total	4160					

Arteriosclerosis has been singled out from the circulatory diseases because of its frequency of occurrence. Patients who died of this disease had a relatively low mean brain weight. The weight was relatively low also for men who died of cancer. For these categories the means are about 100 grams lower than the mean for violent and accidental deaths. For the other categories of the causes of death, the mean weights lie between the two extremes. Of the various disease groups, tuberculosis shows the highest mean weight, but this weight is only 51 grams above the lowest weight, that for arteriosclerosis. The differences certainly are not striking.

Since there are usually two causes of death for each case, the above differences refer to arrays almost twice as extensive as any to which we can refer in other sections of this paper. The mean differences, even if they are quite small, are therefore more likely to have statistical significance. Yet it turns out that only the mean weight differences between tuberculosis and arteriosclerosis, and between tuberculosis and the nervous diseases, are more than six times their probable errors. The mean differences between tuberculosis and cancer, and between tuberculosis and the circulatory diseases are more than four times, but less than six times, their probable errors. And only in the two extreme categories (arteriosclerosis and the violent and accidental deaths) do the mean weights differ from the mean for the total non-lesioned array by more than four times the probable errors. In short, not much significance can be attached to most of these differences, though of course they cannot be dismissed as negligible.

Another analysis suggested itself, namely, of how the post-mortem brain-weight trends may differ for various causes of death. Table 8 gives the mean brain weights for certain causes, by hours post mortem. It should be understood that this study, like the preceding one, is merely an initial survey.

The number of hours post mortem is known for only 1544 cases, and for only 2789 causes of death (299 causes are not specified). In spite of the reduction in the number of causes one more general category and five more specific categories of the causes of death have been added to the list. Let us consider first the mean weights for the categories given, without reference to the post-mortem variations. For cancer, for all of the cases in the abridged list (that is, that for which the hours post mortem are given), the mean weight is now 13.5 grams higher than it was for the unabridged list (the total array of non-lesioned-brain cases).

TABLE 8

Mean brain weights by hours post mortem, for selected causes of death
(Non-lesioned-brain cases)

I. *General disease categories*

	No.	*All hours*	*0–5 hours*	*6–11 hours*	*12–17 hours*	*18–23 hours*	*24–35 hours*	*36–146 hours*
Diseases of the respiratory system	768	1297.5	1272.4±11.0 (67 cases)	1275.0± 7.7 (116 cases)	1284.2± 7.0 (164 cases)	1310.3± 7.5 (136 cases)	1306.0± 6.9 (150 cases)	1323.3± 7.0 (135 cases)
Diseases of the circulatory system	698	1290.5	1245.7±10.4 (69 cases)	1268.8± 7.5 (101 cases)	1300.8± 7.7 (122 cases)	1282.1± 6.8 (140 cases)	1297.2± 7.1 (144 cases)	1325.4± 7.1 (122 cases)
Infectious diseases	466	1323.2	1294.0±11.0 (50 cases)	1306.0± 9.4 (84 cases)	1307.0± 9.9 (86 cases)	1357.9±10.1 (76 cases)	1324.1± 7.9 (85 cases)	1341.8± 8.2 (85 cases)
Diseases of the nervous system	322	1273.9	1228.4±14.5 (37 cases)	1251.8±10.7 (57 cases)	1245.0± 8.4 (80 cases)	1319.8±12.9 (53 cases)	1281.8±12.4 (44 cases)	1322.6±11.7 (51 cases)

			0–11 hours	*12–23 hours*	*24–35 hours*	*36–146 hours*
Diseases of the digestive system	215	1306.3	1273.6± 8.6 (72 cases)	1305.3± 9.5 (85 cases)	1323.8±10.7 (42 cases)	1412.5±13.6 (16 cases)
Diseases of the urogenital system	151	1298.3	1259.4±14.3 (32 cases)	1280.0± 9.7 (70 cases)	1288.5±11.6 (26 cases)	1419.6±18.8 (23 cases)
Cancer	83	1288.5	1250.0±10.8 (27 cases)	1310.5±15.3 (38 cases)	1261.1±28.2 (9 cases)	1338.9±11.0 (9 cases)

		0–11 hours	*12–23 hours*	*24–146 hours*
Cause not specified	299	1287.1± 8.1 (105 cases)	1313.6± 8.7 (107 cases)	1336.2± 8.5 (87 cases)
Miscellaneous	86			
Total	3088			

TABLE 8 (*Continued*)

Miscellaneous	86
Total.....	3088

TABLE 8 (*Continued*)

II. *Specific disease categories*

	No.	*All hours*	*0–5 hours*	*6–11 hours*	*12–23 hours*	*24–35 hours*	*36–146 hours*
Tuberculosis	389	1325.6	1291.0±12.5 (39 cases)	1308.9± 9.8 (73 cases)	1328.6± 8.2 (131 cases)	1334.5± 8.1 (71 cases)	1346.0± 8.4 (75 cases)
Bronchopneumonia	347	1304.8	1237.0±16.8 (23 cases)	1285.5±11.6 (31 cases)	1310.0± 9.2 (140 cases)	1303.4±10.5 (73 cases)	1323.8± 9.7 (80 cases)
Arteriosclerosis	277	1269.9	1200.0±14.2 (28 cases)	1241.7±12.4 (36 cases)	1280.3± 7.3 (119 cases)	1287.7±11.2 (53 cases)	1289.0±10.7 (41 cases)
Pneumonia, unspecified.....	260	1274.2	1254.6±14.1 (22 cases)	1250.0±10.9 (59 cases)	1275.5± 8.3 (106 cases)	1284.2±11.8 (41 cases)	1315.6±12.7 (32 cases)
Paresis	230	1257.8	1193.3±12.5 (30 cases)	1230.5±12.6 (41 cases)	1260.9± 9.3 (92 cases)	1250.0±15.4 (27 cases)	1332.5±14.2 (40 cases)

			0–11 hours	*12–23 hours*	*24–35 hours*	*36–146 hours*
Myocarditis	181	1299.7	1268.4±11.6 (38 cases)	1274.5±11.8 (49 cases)	1312.2±14.0 (45 cases)	1337.8±12.3 (49 cases)
Cardiorenal diseases.....	85	1312.4	1290.9±15.5 (22 cases)	1325.8±15.5 (33 cases)	1294.4±18.0 (18 cases)	1341.7±19.4 (12 cases)

III. *Acute and chronic diseases*

	No.	*0–5 hours*	*6–11 hours*	*12–17 hours*	*18–23 hours*	*24–35 hours*	*36–146 hours*
Acute diseases.....	607	1250.0±11.0 (45 cases)	1262.2±8.3 (90 cases)	1268.3±7.4 (131 cases)	1325.7±8.1 (115 cases)	1296.5±8.0 (114 cases)	1321.4±7.8 (112 cases)
Chronic diseases.....	1560	1251.9± 6.8 (161 cases)	1277.5±5.1 (247 cases)	1280.3±4.9 (307 cases)	1309.2±5.1 (289 cases)	1303.3±4.7 (285 cases)	1338.6±4.9 (271 cases)
Differences.....		+1.9	+15.3	+12.0	−16.5	+6.8	+17.1

For the nervous diseases the weight is 11.5 grams lower, and for the urogenital diseases it is 16.7 grams lower, than it was in our first survey. A new and very high mean is the one which has been added to the list of general categories, namely that for the infectious diseases as a group. Among the more specific categories is pneumonia, unspecified, with a mean weight 23.3 grams lower than the weight for the respiratory diseases as a group, and cardiorenal disease, with a mean 21.9 grams higher than the mean for the circulatory diseases as a group.

Now let us try to estimate the differences between the mean weights as they may have existed at the time of death. During the early hours post mortem the mean weights differ considerably, therefore it may be inferred that they differed at the time of death. Three hours after death the mean weight for the complete array of cases for which the hours post mortem are given is estimated to have been about 1262 grams; six hours after death it is estimated to have been about 1275 grams. These values must serve as standards with which to compare the weights for the selected causes of death for the corresponding times post mortem.

The mean weight for the infectious diseases for the earliest period post mortem is relatively high. It is not quite as high for the respiratory diseases. The weights are relatively low for cancer, the nervous, the circulatory, and the urogenital diseases. For the digestive diseases the mean weight is near the mean for the total array (the standard). For arteriosclerosis and bronchopneumonia the mean weights are relatively low; the weight is lowest of all for the cases of paresis. For myocarditis and pneumonia, unspecified, the weights are only a little below the standard weight. For cardiorenal disease and tuberculosis the weights are relatively high.

It is very doubtful whether these relative differences should be construed to have any precise significance. We cannot take them that way. They indicate, however, that real differences probably exist in the brain weight under different conditions of disease at the time of death. According to Brandes (1927) the brain swells before death under certain conditions of disease; the amount of intravital swelling detectable after death is greatest when death results from infections, toxemias, and acute diseases generally. Possibly the study of the variation of the brain weight can become a useful means of getting at the amount of the swelling, but only after due allowance has been made for the other factors with which the weight of the brain varies so demonstrably.

At the end of the above table are figures which were intended to make comparison possible between the effects of acute disease and the effects of chronic disease. These figures are worthless, and should be ignored; they are presented simply because they emphasize the difficulty of estimating the statistical association between brain weight and the conditions of disease from unadjusted data. We classified 2167 causes of death into acute and chronic categories, and calculated the mean weights by hours post mortem. The mean weights for the first few hours after death turned out to be relatively low and almost identical in the two categories (see table). Undoubtedly this is in part due to the fact that many cases are used in both categories, for each case involves two causes of death, of which one is often acute, the other chronic. The dual use of cases could be avoided by classifying not the causes of death but whole cases according to the acuteness of disease. But the comparison would still be unsatisfactory if that was done. The mean weights would not be comparable in respect to other factors than disease, and we have already demonstrated that other factors affect the variation greatly.

One more aspect of the variation in the brain weight with the causes of death remains to be noticed before we enter into a discussion of the implications of our findings. It is this. With the passage of time post mortem all of the mean weights show a general tendency to rise, regardless of the causes of death. To this finding there is no exception. The grouping of the data has been arranged to bring this point out especially. It can no longer be doubted that the weight of the brain increases after death: the increase is a general phenomenon. The typical increase has been described for this array of cases, but we now see that the increase may vary both in amount and in rate. The conditions of variation remain to be explored.

DISCUSSION

Work on the weight of the brain has never been very closely allied with work on the physiology of this organ. At the outset of our study we were aware, of course, that our work was related to that which has been done on the volume of the brain, but not until our initial surveys were far advanced did we perceive any relation of our work to the investigation of the fluid equilibria of the brain. The literature in this field is voluminous, and a complete review of it is not necessary here.

Some of the earliest attempts to measure the amount of brain swelling that accompanies various diseases are those reported by Martin Reichardt from the psychiatric clinic at Würzburg. Reference may be made especially to one of Reichardt's papers of 1914 (b), though two other papers which deal with intravital and post-mortal brain swelling may be cited. Working on human cadavers and on dogs, Reichardt measured the capacity of the skull and the specific gravity of the brain, determined the percentage difference between these two measurements, and estimated the amount of fluid that surrounded the brain. He also measured the brain weight. He found that human brains of high weight may fill the cranial chamber to capacity, and that brains of lower weight may fail to do so in varying degrees. Reichardt was convinced that the amount of cerebral swelling increased with the duration of the terminal illness and with its intensity. He believed, too, that it increased with the lapse of time between death and autopsy. He made a clear distinction, at least in theory, between intravital and post-mortal swelling, though he found it difficult to distinguish between them in fact. He concluded that intravital swelling varies with the conditions of disease. He did not succeed in establishing a correlation between the size of the brain and the number of hours post mortem. Reichardt presented some data on the swelling of brain substance in 10 percent formalin, but no data as crucial as those of Kato, which will be presented presently. Reichardt's papers of 1914 and 1915 are devoted in part to controversy with Stefan Rosenthal, his foremost critic. Rosenthal's papers (1914) contain no data on terminal brain swelling.

The methods developed by Reichardt were used by Schultze, who announced in 1923 that the amount of cerebrospinal fluid obtainable from the human body at autopsy decreases with the lapse of time after death. Schultze's measurements were extended by his student, Brandes (1927), who sought to find out how various conditions of disease affect the volume of the cerebrospinal fluid. While working as an assistant in the pathological institution of the state hospital at Braunschweig, Brandes made nearly 200 measurements of the volume of the cerebrospinal fluid in cadavers, and made correlative measurements on the specific gravity of the brain and on the capacity of the skull. He came to the conclusions that the brain swells as the amount of cerebrospinal fluid decreases, that the swelling is due to the absorption of this fluid, and that the amount of swelling varies with conditions of disease. To

account for the absorption of fluid Brandes appealed to Höber's findings on membrane permeability (1925; but see also 1926).

According to Brandes the amount of swelling is greatest when death is due to infections, toxemias, and acute diseases generally. The evidence on this point needs to be considered in detail, because it emphasizes the distinction between intravital and post-mortal swelling. Like his predecessors Brandes measured the relative size of the brain in terms of the percentage difference between the specific gravity of the brain and the capacity of the skull. The difference as it exists in life can only be estimated, of course. Brandes was inclined to place it at 10 percent, with a normal variation possibly from 6 to 14 percent. When the difference is as low as 6 percent, Brandes thought there might be no symptoms of increased cerebral pressure, whereas if it fell to 1 percent or less normal life would be impossible. With the 6 percent limit in mind, Brandes' findings for the acute and chronic diseases may be compared (Table 9).

The differences at death must be estimated from the differences for the first 5 hours after death. For the acute diseases this mean difference is stated to be 6.5 percent, therefore at the time of death the difference

TABLE 9

Mean differences between brain size and skull capacity in percent

HOURS POST MORTEM	ACUTE			CHRONIC		
	Cases	Mean age *(yrs.)*	Mean difference between specific gravity of brain and skull cap'y. *(percent)*	Cases	Mean age *(yrs.)*	Mean difference between specific gravity of brain and skull cap'y. *(percent)*
1–5	19	45	6.5	45	48	9.6
5–10	22	42	5.0	33	45	8.8
10–15	19	42	3.4	18	53	9.0
15–20	8	39	3.4	10	46	5.6
	68	42.5		106	47.7	
Change in 20 hours:			3.1			4.0

tends to be near the lower limit of normality (6 percent). For the chronic diseases the mean difference is stated to be 9.6 percent, therefore at the time of death the difference tends to be near the mean normal value (10 percent). Intravital swelling certainly occurs in cases of acute disease, but no appreciable amount of it seems to occur in cases of chronic disease. *After* death swelling continues. Brandes' figures are conclusive on this point only for the acute diseases, but Brandes agrees with Schultze and with the other students of the problem whom he mentions in his paper, in finding that post-mortem swelling is a general phenomenon. The change during the first 20 hours after death amounts to 3.1 percent for the cases of acute disease, and 4.0 percent for the cases of chronic disease. It seems that the mean differences become more nearly equivalent with the passage of time after death. That is, after death, the swelling seems to become progressively less dependent on the conditions of disease, and more dependent on other factors which determine the limits of increase.

In the course of studies on the effects of various histological fixatives, Kato (1938) made some measurements of the swelling of two human brains preserved in 10 percent non-neutral formalin. In the first 24 hours after death one of Kato's specimens gained 6.3 percent in weight, the other 3.4 percent. This was not intracranial swelling, and the osmotic conditions were probably different from those that exist inside the skull, but the mean increment was comparable to the increase in mean weight which we think occurred intracranially in our cases in the same period after death. The maximum swelling of Kato's specimens in formalin, namely 10-11 percent, was reached in 3-4 days. Subsequent observations showed that the brains remained unchanged for about 3 months, then the swelling began to go down.

In order to determine the effects of injury to the head on the swelling of the brain, Shapiro and Jackson (1939) made some determinations of the amount of cerebrospinal fluid which can be collected at autopsy from the subarachnoid spaces, the spinal cord, and the ventricles. The amount of fluid varied between 30 and 60 cc. for normal (i.e., not traumatized) specimens. This estimate agrees well with that of Brandes, which was 50 cc. From cases of head trauma only 5 or 10 or at the most 15 cc. of fluid could be collected by Shapiro and Jackson from the subarachnoid spaces, and this was usually found in the basal cisterns and in the spinal subarachnoid spaces. Often the cerebral subarachnoid spaces were so dry that the normal lustre of the

pia mater had disappeared. At the same time the lateral ventricles were dilated with 30-60 cc. of fluid which did not run freely into the subarachnoid spaces even when the brains were removed. The enlargement of the brains seemed to be accounted for, at least in part, by this internal traumatic hydrocephalus. Dehydration of samples of traumatized and untraumatized specimens showed that the former contained a slightly lower percentage of water than the others. The conclusion was reached that the traumatized brain is swollen but not edematous, that it contains not more water than normal but more blood, and that it appears to be dry, the subarachnoid fluid being decreased in quantity, the ventricular fluid being increased.

The Monro-Kellie doctrine of the constancy of the intracranial volume is apparently an old story (Weed, 1922, 1933), though it is a new one to us. It suggests some interrelations between our findings. In its amended form this doctrine states that the entire central nervous system is enclosed in a bone-supported sac of sufficient rigidity to keep the contents relatively constant in volume. Weed and his collaborators (Clark, Flexner, Hughson) have demonstrated that there is some provision for elasticity in the system, since with change of posture there is some dislocation of fluid from one part of the subarachnoid space to another; but the expansibility of the dural sac is negligible. Now, the contents of this sac include the brain and spinal cord, the cerebrospinal fluid, and varying quantities of blood. The quantity of any one of these elements may change, but a reciprocal and compensatory change must occur in the quantity of one or both of the remaining elements, if the intracranial volume is to remain constant. Weed and his co-workers have showed that such compensatory changes do occur. In 1919 Weed and McKibben ascertained that intravenous injections of solutions whose osmotic pressures differ from that of the blood alter the pressure of the cerebrospinal fluid, and change the volume of the brain. Strongly hypertonic solutions cause a lowering of the pressure of the cerebrospinal fluid, and produce a striking diminution in the volume of the brain. Isotonic solutions, when injected in quantity, cause some swelling of the brain, and hypotonic solutions cause marked swelling.

Certain implications of our findings are now clear. Some of the variation in the brain weight must be intracranial, namely, that which occurs with age, with time post mortem, or with varying conditions of disease, in mature persons. Furthermore, insofar as the variation in weight is intracranial, it is physiological or pathological; that is, it

might occur in any brain, regardless of the morphology of the brain itself. It is true that slight morphological changes in the brain occur with age (the work of Andrew, 1939, has already been mentioned), but Donaldson, working for years on human brains, found no essential differences in structure between large and small brains. In his later papers (1925, 1932) Donaldson emphasized the fluid environment of the brain rather than its structure. He found marked differences in vascularization between the brains of outstanding men and those of lesser men, and he was inclined to attribute superior mental performance to superior blood supply.

Any change in the brain weight after the skull has grown to maximal size must be attributed to changes in intracranial conditions. It ought to be possible to adjust adult brain weights for age and for skull dimensions, and to estimate the variation in weight after death for selected causes of death. Some estimate of the partial or net correlation of the brain weight with age, head size, time post mortem, and certain conditions of disease should be possible with the more complete records at our disposal, and perhaps some estimate, too, of the total intracranial variation. Studies of this kind are now in progress on the 631 cases for which we have the essential data.

It remains to be discussed whether or not the variations observed in our material should be considered normal. We must not overlook the fact that the data used in the present study came from a mental hospital. The brains from which the weighings were made were apparently non-lesioned, however. Of course, we have yet to determine whether the weights were increased beyond normal through brain swelling under various conditions of disease; the post-mortem variations show that they may have been. And we must ascertain whether, relative to the skull dimensions, the brains were really light in weight at all ages, as they appeared to be. In other words, the brains may be either lighter or heavier than "normal"; we do not know what the normal weight is, nor how widely it may vary. Until we finish the studies we are now carrying on, it would be pointless to speculate at length about the relations of disease to the variations in weight which we have presented. Even if the weights we have available prove to be abnormal, quite possibly advantages for study may be found in the selected character of the material. It may be that the normal limits of intracranial variation can only be ascertained by studying material which varies beyond those limits.

Our initial findings have reminded us of Bancroft's (1931 and after) theory of the reversible coagulation of nerve proteins by hydration and dehydration, and of his postulate that there must be two types of insanity, a "coagulation" type and a "dispersion" type, in which the colloids of the brain are oppositely affected by hydration and dehydration. But our findings have reminded us, too, of Cannon's work on physiological homeostasis (1929, 1932), and of Bancroft's demonstration (1934, 1938) that Claude Bernard's dictum about the constancy of the *milieu interieur* as the condition of a free life can be applied quite generally to problems of mental behavior.

SUMMARY AND CONCLUSIONS

A basis for this work was provided by data derived from 2752 male white autopsies. Measurements from 2080 non-lesioned-brain cases have been used particularly. This series of cases is much more extensive than any similar one which has been available heretofore from a single source.

The variation of the brain weight has been appraised by skull length, skull breadth, age at death, the lapse of time between death and autopsy, and certain selected causes of death. The study is not yet completed, for the net or partial correlation of each of these variables with the brain weight remains to be determined. Insofar as the brain weight varies with skull length or skull breadth it is a matter of head size; but we are not yet ready to estimate how much of the brain-weight variability is an index of head size. Insofar as the brain weight varies with age, hours post mortem, and conditions of disease, in persons whose skulls have grown to mature size, it is intracranial, that is, it is physiological or pathological; and it does not seem to be dependent so much on the morphology or shape of the brain as on the fluid equilibria inside the skull.

From physical maturity to advanced old age the mean weight of the brain seems to vary inversely with the age at death. This is not a new finding, but it is one which can now be demonstrated for all ages up to 96 years. The brain weight decreases continuously, and apparently at a uniform rate, the maximum decrease between ages 25 and 96 being about 11 percent of the mean weight for our whole series of non-lesioned-brain cases. These findings are subject to correction when the net correlation of weight with age has been determined. The age of maximum weight remains uncertain, for no adequate statistics are

available on the variation of the brain weight in the early years of life. No estimate can be made as yet of the amount of brain swelling that may occur either normally or because of disease at any stage of life.

Heretofore no evidence has been presented on the post-mortem variation of the brain weight. It is this evidence which may enable us to form an estimate of the intracranial variations for certain conditions of disease. We have found that after death the mean weight of the brain increases at least for some hours and possibly for some days. The weight seems to increase continuously, at a regular but gradually diminishing rate. From the work of others it is inferred that the increase in weight is due to an increase in volume, which in turn is due to the absorption of cerebrospinal fluid. Whether blood is also absorbed we do not know, of course; nor can we furnish any evidence as to whether the absorbed fluid becomes fixed in the colloidal substance of the brain or merely held as free fluid, particularly in the intercellular spaces. But if the weight increase is due to fluid absorption, further inferences are in order. It is probable that the rate of post-mortem increase varies, depending on the amount of brain swelling that has occurred before death. It is probable, too, that the amount of the post-mortem increase is limited by the capacity of the skull, by the amount of unabsorbed fluid, and by the osmotic conditions that prevail.

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NOTES

MENTAL STATUS AND SEASON OF CONCEPTION

IN A recent communication to this journal C. A Mills[1] has given evidence which he interprets to show that mental development is influenced by the season of conception. The evidence supporting the conclusion consists in five distributions, each separating a set of college freshmen according to the months in which the members of the set were conceived. The members of three of the sets are females; two of the sets comprise males. The colleges represented are Kentucky (State University), Kansas (State University), Wisconsin (State University) and the Women's College of the University of North Carolina.

When the frequencies of conceptions per month in the case of the freshmen were compared with the frequencies of conception per month among citizens of the state (determined from the live-birth statistics of the state in question by averaging the observed frequencies of the 6 earliest years available) a disproportionate number of freshmen were observed to have been conceived in months January, February, and March. The differences involved are unquestionably statistically significant.

On the basis of these facts the author writes:

> It would seem that, in general, a child conceived in mid-summer heat is blest with only about 60 percent of the likelihood of college matriculation that is enjoyed by one conceived in late winter . . . Winter conception . . . provides a significant advantage along lines of mental achievement. The higher metabolic level of parental protoplasmic vigor during winter cold seems to be transmitted through the germ plasm, and to exert a lasting effect upon the future course of the offspring . . . It would seem highly desirable, therefore, that parents keep in mind the advantages offered their offspring by winter conception. Even the best hereditary background may be made much more effective if supported by proper season of conception.

[1] Mills, C. A. Mental and physical development as influenced by season of conception. *Human Biology*, 1941, 13, 378-389.

TABLE 1

Conceptions by months in rural Wisconsin (males)

CONCEPTION MONTH	1917	1918	1920	1921	1922	1923	RURAL CONCEPTIONS Mean	RURAL CONCEPTIONS Percent	STATE CONCEPTIONS Mean	STATE CONCEPTIONS Percent
January	1563	1824	1651	1629	1480	2658	1801	8.6	2443	8.0
February	1501	1803	1751	1686	1678	2659	1846	8.8	2215	7.2
March	1553	1719	1588	1678	1542	2552	1772	8.5	2306	7.5
April	1719	1805	1585	1605	1602	2644	1827	8.7	2567	8.4
May	1817	1697	1658	1688	1669	2782	1885	9.0	2499	8.2
June	1705	1653	1602	1590	1560	2427	1756	8.4	2794	9.1
July	1566	1555	1461	1585	1455	2372	1666	7.9	2587	8.5
August	1455	1329	1222	1457	1325	2182	1495	7.2	2668	8.7
September	1579	1417	1335	1469	1313	2228	1557	7.4	2597	8.5
October	1595	1650	1537	1580	1607	2516	1748	8.4	2661	8.7
November	1495	1556	1631	1620	1493	2349	1691	8.1	2723	8.9
December	1713	1893	1666	1786	1609	2797	1911	9.1	2562	8.4

We regard the foregoing conclusions as without adequate foundation in the data given by the author. The analysis which supports this viewpoint follows. Mills' data are described as consisting in samples drawn from a rural population. The samples are compared with the population statistics drawn from the state as a whole. That a difference exists between monthly conception rates in the state of Wisconsin (for example) as a whole, and in the rural sections alone, can be seen by reference to our Table 1. This table gives the frequency of conceptions for males by months in rural Wisconsin for the years 1917-18-20-21-22 and 23 (the years used by Mills), the frequencies being assigned to conception month on the basis used by Mills. The table has been constructed from the reports of the Bureau of the Census. In the final column but one, appears the average

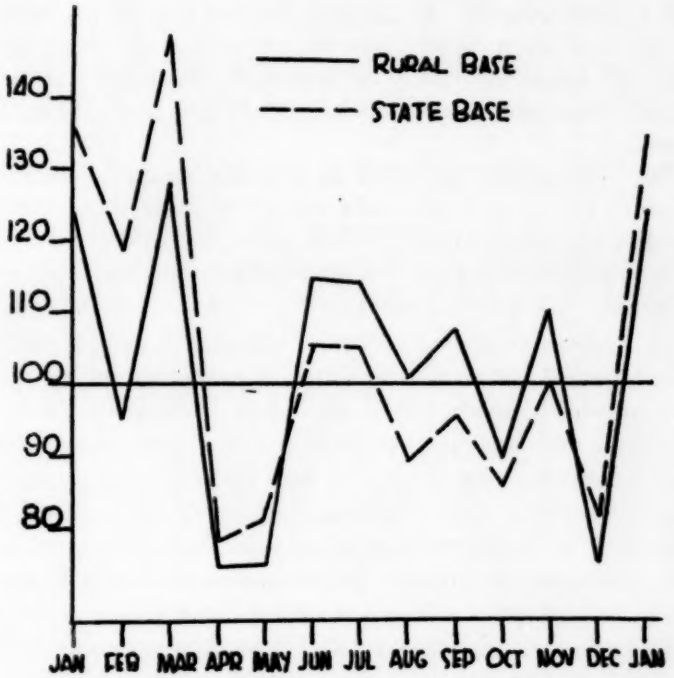

FIG. 1

number of conceptions by month in rural Wisconsin over the 6-year period together with the percent which each month represents of the yearly total; in the final column appear the average number of conceptions by month in Wisconsin as a whole, together with the percent which each month represents of the yearly total. Examination of these figures suggests strongly that the rate of conception drops off in the summer months in rural Wisconsin.

Substituting the rural base for the state base we have prepared Fig. 1. This figure gives the ratio of percent of conception by month referred to the freshmen to percent of conception in the rural population by months. In order to make a comparison, the graph from Mills' study using the state base is given with the graph using the rural base. By inspection it can be seen that the use of the rural base diminishes the ratio in the winter months and increases its magnitude in the summer months. If attention be paid only to the curve using the rural base it can be seen that the variation from month to month, despite its magnitude, loses its systematic character. It is in the systematic character of the variation that Huntington's theory finds its support.

That more variability exists in monthly conception rates among freshmen as well as in the state and rural bases than should occur by chance (i.e. on a Bernouilli hypothesis) is obvious by inspection. For the variability in excess of that permitted in a Bernouillian distribution the following sources may be suspected:

(a) In the collection of statistics pertaining to college matriculation the problem of February admissions requires careful consideration. If the institution involved does not admit students in February that fact clearly will bias the frequencies of the birth months of those admitted. Again if the institution does admit in February care must be taken that these admissions (usually relatively small in number compared with September admissions) are not overlooked in a list of all admissions. Obviously the exclusion of February matriculees will bias the conception statistics of the freshmen.

(b) In those matriculees included in the conception statistics some confusion is bound to be present in respect of the populations which these matriculees represent. Mills reports the matriculees as largely drawn from rural areas. An exact base against which to compare the matriculees would be difficult to determine on that definition.

(c) The method of calculating conception month (counting back 9 months) is inexact and consequently must contribute variability to both distributions, i.e. of freshmen and of base conceptions.

It appears on the basis of this analysis that the substitution of a rural base results in the disappearance of the systematic variation in the frequencies of matriculees conceived in the various months. Consideration of the elements affecting the various statistics needed to handle the problem according to Mills' procedure suggests very strongly that what variability remains over what is allowable on a Bernouillian hypothesis is attributable to the sampling conditions. In the light of this analysis we must reject the startling conclusion that month of conception has an effect upon mental ability.

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MENTAL STATUS AND SEASON OF CONCEPTION

A REPLY TO THE CRITICISM OF MALCOLM G. PRESTON

PRESTON'S criticism of my article is based upon one main point, and his selection of even this point seems entirely unwarranted. Perhaps, in attempting to save publication space, I failed to express my meaning with sufficient clarity.

In my study, I selected the four state universities (Wisconsin, Kansas, Kentucky, and North Carolina) because their students were drawn from so-called rural states, thus allowing me to observe possible latitude differences in temperature effects. State universities were chosen because their student body is more truly representative of the state population than is the student body of Harvard University, for instance, or any other private or semi-private school. These latter tend to draw a disproportionate number of their students from urban populations. I made no investigation of the percentage of students actually rural in origin, nor could the universities supply me with such data. I would point out, however, that these four states, in the 1920 census, showed the following percentages of rural population:

Wisconsin	53	Kentucky	74
Kansas	65	North Carolina	81

Since only 53 percent of the Wisconsin population was rural at the time the students in question were being born, it would seem obvious that no justification exists for Preston's criticism or for his recalculation of my Wisconsin data on the basis of purely rural births.

The four universities in question did contain freshmen admitted in February (although very few), and these were all included in the study.

Regarding Preston's criticism of my use of the 9-month conception period, I see no reason why this would introduce any significant error. It would have been possible to calculate the conception time of the students more accurately, because their exact dates of birth were available. Such was not the case, however, with the state birth data. Perhaps Preston can suggest more specifically just what inaccuracies might accrue from applying the 9-month conception period alike to both classes of births.

It is Preston's privilege to reject my conclusions if he so desires, but his stated grounds for doing so seem clearly untenable.

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RECENT LITERATURE

USEFUL IN THE STUDY OF HUMAN BIOLOGY

In this department will be noticed the books and reprints which are currently received at the Editorial Office. Publications intended for notice here should be addressed to Dr. Lowell J. Reed, Editor of Human Biology, 615 North Wolfe Street, Baltimore, Maryland, U.S.A.

I. EVOLUTION AND GENETICS

1. *Evolution — General Principles*

OSBORN, HENRY FAIRFIELD. [Ed. by Mabel R. Percy.] Proboscidea. A Monograph of the Discovery, Evolution, Migration and Extinction of the Mastodonts and Elephants of the World. Vol. II. Stegodontoidea, Elephantoidea. *New York* (American Museum Press), 1942. Pp. 805-1675 + 30 plates. 12½ × 10¾ inches. $20.00. [Bibliography of 7½ pages.]

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2. *Human Evolution*

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4. *Genetics — General Principles*

LEVI, WENDELL MITCHELL. The Pigeon. With a Preface by Oscar Riddle. *Columbia, S.C.* (R. L. Bryan Co.), 1941. Pp. xxxii + 512 + 2 colored plates. $10.00. [Bibliography of 13½ pages.]

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5. *Human Heredity*

ILIN, M., and E. SEGAL. How Man Became a Giant. *Philadelphia* and *New York* (J. B. Lippincott Co.), 1942. Pp. 270. 8¼ × 5½ inches. $2.00.

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II. GROUP BIOLOGY

1. *Environment of Man*

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24. Japanese population by nativity or citizenship in selected cities in the United States: 1940. Pp. 1, Dec. 10, 1941.

25. Japanese population of the Pacific coast states by sex and nativity or citizenship, by counties: 1940. Pp. 4, Dec. 10, 1941.

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24, Missouri; 25, Virginia; 26, Kentucky; 27, Indiana; 28, Washington; 29, Nebraska; 30, North Carolina; 31, Louisiana; 32, Alabama; 33, Oklahoma; 34, Maryland; 35, Minnesota; 36, New Jersey; 37, Georgia; 38, Massachusetts; 39, Oregon; 40, Wisconsin; 41, Florida; 42, Ohio; 43, California; 44, Michigan; 45, Illinois; 46, Texas; 47, Pennsylvania.

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1. Foreign-born Germans and Italians in selected cities of the United States. Dec. 12, 1941. Pp. 2.

2. Foreign-born Germans and Italians in the United States by states. Dec. 12, 1941. Pp. 2.

3. Citizenship of the foreign-born white population of the United States by states. Dec. 13, 1941. Pp. 2.

5. Japanese population in selected counties and cities of the United States by sex and nativity or citizenship: 1940. Dec. 19, 1941. Pp. 9.

8. Preliminary figures on employment status, occupation, and industry for the Japanese population of the territory of Hawaii: 1940. Feb. 2, 1942. Pp. 3.

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[Vacant]

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